eFuse IC TCKE6 Series
Application Note

Overview

An eFuse IC is a protection IC equipped with various functions to protect electronic devices, serving as an alternative to conventional fuses, and is also known as an electronic fuse.

In this document, with a maximum input rating of 40 V and output current of 2.5 A, we explain the basic usage of the TCKE6 series eFuse IC, which incorporates basic protection functions, as well as the operation of various features (short-circuit protection, overcurrent protection, overvoltage protection, overheat protection, undervoltage lockout, and others).

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1. Introduction

Currently, components such as fuses and PolySwitches (resettable fuses, polyfuses) are widely used as safety devices to prevent overheating and ignition in various electronic devices. All of these are protective devices that utilize Joule heat generated by currents exceeding the rated value, but in this document, we refer to these as conventional fuses.

Glass tube fuses and chip fuses protect circuits and prevent device destruction by interrupting or limiting current flow through the melting of internal metal parts, while PolySwitches do so by a rapid increase in resistance caused by the thermal expansion of conductive polymers.

However, all of these have disadvantages such as low accuracy in operating current, large variations in cutoff current, and the use of Joule heat resulting in a delay before protection is activated.

Additionally, fuses that use melting metal are irreversibly destroyed, requiring replacement of the fuse itself, which is another disadvantage.

eFuse ICs (electronic fuses) are products that solve the various disadvantages of the conventional fuses mentioned above by using MOSFETs to interrupt current flow. In addition to being used in the same way as conventional fuses, being ICs allows them to incorporate various protection functions beyond just overcurrent protection.

This application note explains the main characteristics, operation, usage, and applications of the TCKE6 series, which incorporate overcurrent protection (OCP), short-circuit protection (SCP), slew rate adjustment (inrush current suppression), overvoltage protection (OVP), and undervoltage lockout (UVLO) functions. Some of these functions have adjustable settings, enabling effective protection of circuits and devices.

2. What is an eFuse IC?

2.1. How to use eFuse IC

eFuse ICs interrupt current using a semiconductor switch, instead of melting alloy parts as in conventional fuses. When the detection circuit senses excessive current, its output signal controls the built-in MOSFET to limit or interrupt the current. Figure 2.1 shows a block diagram of using an eFuse IC for power supply to a PMIC (Power Management IC).

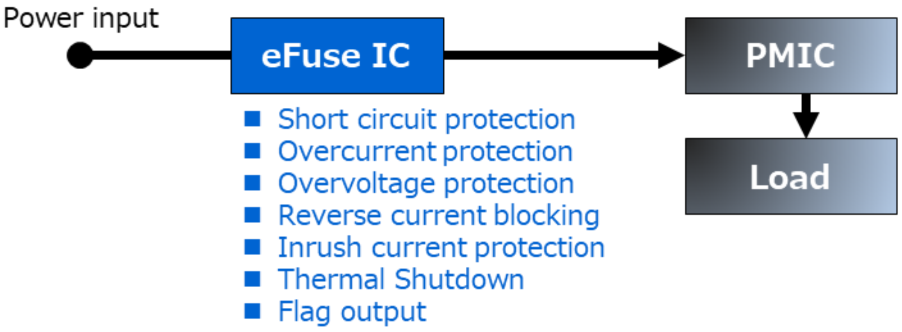

Figure 2.1 Example of eFuse IC usage・Main function examples

In this example, an eFuse IC is inserted into the PMIC power line in place of a conventional fuse. If an abnormality in the PMIC itself or in the downstream circuit causes overcurrent, the eFuse IC limits or interrupts the current to protect the circuit and helps prevent the device from emitting smoke or catching fire.

2.2. Benefits of using eFuse IC

When using eFuse ICs, the following benefits can be expected.

- Reduction of maintenance costs and time by eliminating the need for replacement

With eFuse ICs, the built-in MOSFET is turned off to interrupt the current, so the device is not destroyed by a single overcurrent event. By turning the MOSFET back on, current can flow again and normal operation can be restored. Unlike conventional fuses that are irreversibly melted, eFuse ICs can be used repeatedly, eliminating the need to replace parts and reducing the costs and time required for repairs and maintenance.

- Robust protection performance through highly accurate current and voltage protection functions

Traditional fuses use melting or thermal expansion, making it impossible to precisely determine the current at which conduction is interrupted. Therefore, when selecting a fuse with a rated current that has a certain margin to avoid malfunction for the expected load current, there remains a risk of destruction. In contrast, eFuse ICs can provide highly accurate protection against overcurrent. Additionally, the TCKE6 series features overvoltage protection and configurable overcurrent protection, delivering robust protection performance against both current and voltage.

- Improved reliability through fast protection operation

With conventional fuses, it takes time for the temperature to rise due to Joule heating until the fuse material reaches its melting point, resulting in a time lag between the occurrence of overcurrent and interruption. During this period, overcurrent continues to flow, but with eFuse ICs, the switch can be turned off almost simultaneously with overcurrent detection, greatly shortening the duration of overcurrent flow. This reduces damage to equipment and improves long-term reliability.

- Cost reduction and miniaturization through integration of various protection functions into a single package

As the name suggests, eFuse ICs are ICs, allowing integration of various functions such as overcurrent protection, short-circuit protection, overvoltage protection (which is impossible with conventional fuses), inrush current suppression (slew rate control), overheat protection, and reverse current prevention into a single package. Compared to implementing these functions with discrete passive components or multiple ICs, this greatly reduces the number of parts and labor, as well as shrinks the mounting area, contributing to cost reduction and miniaturization.

3. Example of peripheral circuits for the TCKE6 series

The TCKE6 series is a 1-input, 1-output eFuse IC with a maximum operating voltage of 30 V. It is equipped with protection functions such as adjustable overcurrent protection via external resistors, short-circuit protection, undervoltage lockout, and overheat protection, among others. Additionally, depending on the product, you can select the FLAG pin, MODE pin for choosing the recovery mode, or the EN pin. For details on the functions of these pins and how to determine external components, please refer to Chapter 6.

3.1. Precautions for peripheral circuits

When the short-circuit or overcurrent protection function operates and the current drops sharply, there is a risk that a high spike voltage may be generated by the counter electromotive force of the inductance components in the wiring connected to the input/output terminals of the TCKE6 series. Below are some example countermeasures.

In PCB design, please design the pattern so that the wiring length on both the input and output sides of the TCKE6 series is as short as possible. Also, make the GND wiring area as wide as possible to lower impedance.

On the input side, for positive spike voltages that occur, the input capacitor C_{IN} serves to suppress the peak value. There is the following relationship between the spike voltage peak value V_{SPIKE} and the capacitance value of C_{IN}, and by increasing C_{IN}, the spike voltage can be reduced.

$$V_{SPIKE} = V_{IN} + I_{OUT} \times \sqrt{\frac{L_{IN}}{C_{IN}}} \qquad (3-1)$$

V_{SPIKE}	:	Peak value of generated spike voltage	(V)
V_{IN}	:	Input voltage during normal operation	(V)
I_{OUT}	:	Output current	(A)
L_{IN}	:	Effective inductance of input terminal	(H)
C_{IN}	:	Input capacitor capacitance	(F)

In the TCKE6 series, it is recommended to implement CIN with 1 μF or more but always make sure that V_{SPIKE} does not exceed the absolute maximum rating by checking with the actual device. Also, if V_{IN} is high, the output voltage V_{OUT} will also be high, and since the current change during short-circuit or overcurrent protection is large, V_{IN} or V_{OUT} may become unstable, causing unstable operation and possibly resulting in IC destruction.

TCKE6 series input side, by connecting a TVS diode (ESD protection diode) or a Zener diode, you can protect against ESD (electrostatic discharge/surge) and transient overvoltage. If a negative spike voltage generated on the output side exceeds the rated value, it is necessary to connect an SBD (Schottky Barrier Diode) to prevent the output potential from dropping significantly below GND. The SBD is effective not only for the TCKE6 series, but also for protecting ICs and devices connected as loads. Please connect the SBD between the VOUT terminal and GND terminal of the TCKE6 series, with the anode on the GND side. In this way, you can further enhance the protection of the TCKE6 series, so it is recommended to use both a TVS diode or Zener diode together with an SBD for the TCKE6 series. An example of the peripheral circuit in this case is shown in Figure 3.1.

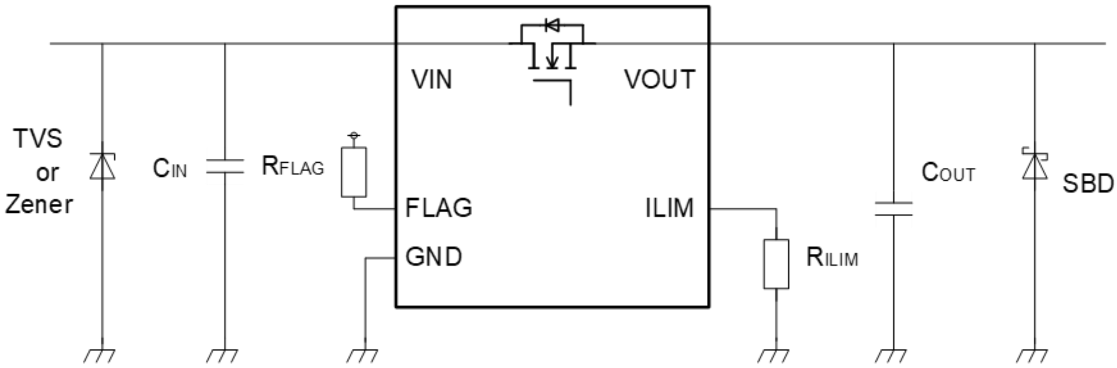

Figure 3.1 TVS/Zener diode, Example of peripheral circuit for TCKE6 series using SBD together

As examples of Zener diodes and SBDs to use with the TCKE6 series, there are the CUHZ series and CUHS20S40. For product details and usage instructions, please refer to the links below.

- Zener diode CUHZ series details here → Click Here
- Schottky Barrier Diode CUHS20S40 details here → Click Here
- Zener diodes effective for overvoltage protection and ESD protection diodes (Application Note) → Click Here
- For the voltage level of the signal line to be protected, what should be the criteria for selecting ESD protection devices? (FAQ) → Click Here
- How to select TVS diodes (ESD protection diodes) (FAQ) → Click Here
- Precautions for TVS diode (ESD protection diode) board design (FAQ) → Click Here

4. Built-in functions of the TCKE6 series

The TCKE6 series has basic protection functions built in as an eFuse IC, as shown in Table 4.1.

Table 4.1 TCKE6 Series Built-in Function Type List

	Overcurrent Protection	Short-circuit Protection	Overvoltage Protection	Overheating Protection	Slew rate Adjustment	Reverse current prevention	FLAG output	Discharge
Built-in / Not built-in	Built-in	Built-in	Built-in	Built-in	Built-in	Not built-in	See Table4.2	Built-in
Setting value adjustability	Possible	Possible (Overcurrent protection Determined by setting value)	–	–	–	–	–	–

Table 4.2 shows the product list of the TCKE6 series.
Depending on the product, the type of auto-recovery operation and functions of each terminal differ.

Table 4.2 TCKE6 Series Built-in Function Type List

Product name	Overvoltage clamp Threshold value	V_{EN} Operation	Return operation type	FLAG function	Package
TCKE601RA	32.0 V (Typ.)	–	Auto-retry	Yes	TSOP6F
TCKE601RL		–	Latched	Yes	
TCKE602RM		–	Selection type	–	
TCKE603RA		Active High	Auto-retry	–	
TCKE603RL		Active High	Latched	–	

Figure 4.1 shows the terminal connection diagram of the TCKE6 series.

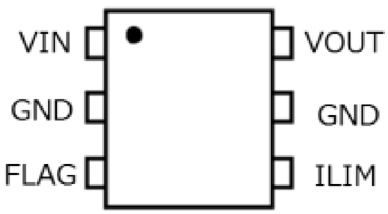

Figure 4.1 Pin Assignment Diagram TCKE601RA, TCKE601RL

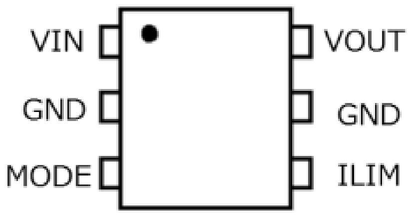

Figure 4.2 Pin Assignment Diagram TCKE602RM

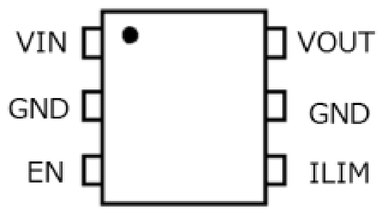

Figure 4.3 Pin Assignment Diagram TCKE603RA, TCKE603RL

5. Block diagram of the TCKE6 series

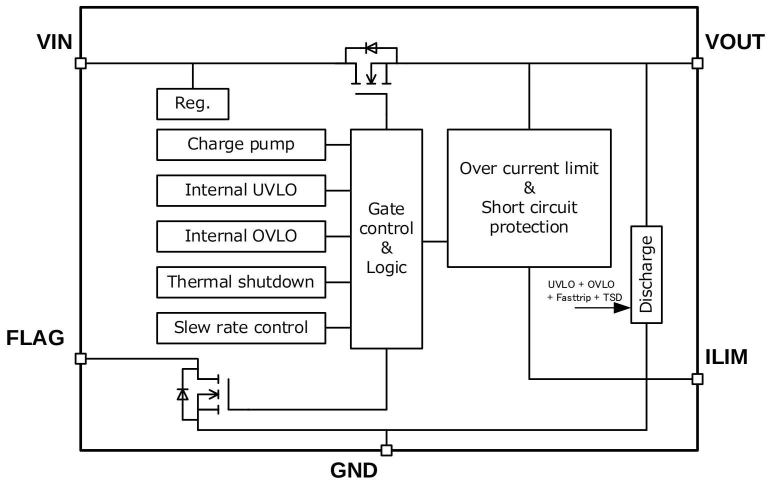

Figure 5.1 TCKE601Rx Block Diagram

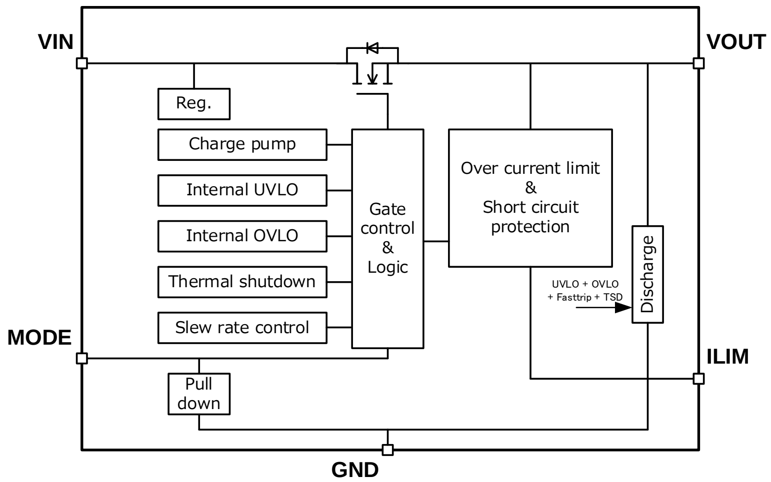

Figure 5.2 TCKE602RM Block Diagram

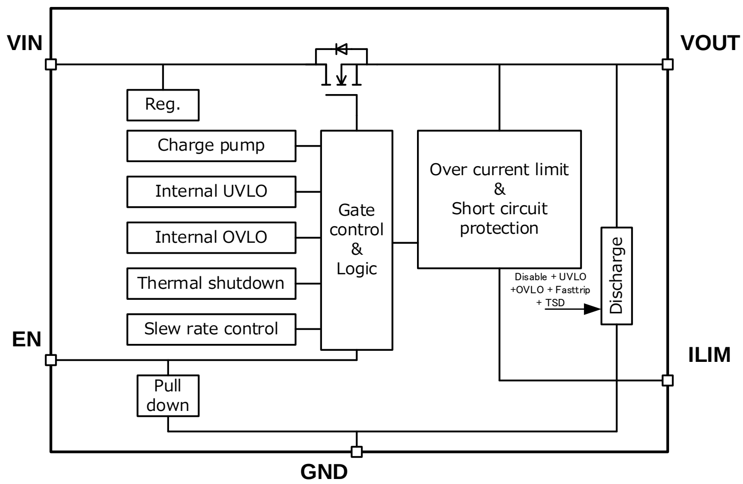

Figure 5.3 TCKE603Rx Block Diagram

Table 5.1 TCKE6 Series Pin Description

Pin Name	Terminal Description
EN	This is the output enable terminal. It is active high.
ILIM	This terminal adjusts the overcurrent limit value. Do not apply voltage externally. The overcurrent limit value is adjusted by the resistance connected between the ILIM terminal and the GND terminal.
FLAG	This is the FLAG output terminal. When the IC detects an abnormal condition, such as overheating, it outputs a signal externally. IC Since it is configured as open drain, please connect an external pull-up resistor.
MODE	This is the MODE switching terminal. When a High level is input, the recovery operation type becomes auto-retry type. When a Low level is input or open, the recovery operation type becomes latch type.
VIN	This is the input power supply terminal.
GND	This is the ground terminal.
VOUT	This is the output terminal.

6. Description of various circuits in the TCKE6 series

6.1. Charge pump circuit

The charge pump circuit is a step-up circuit that generates the gate drive voltage for the Nch MOSFET used as a switch.

6.2. Operation of the overvoltage protection circuit (OVLO)

The overvoltage protection circuit is a circuit that stops output when an input voltage exceeding the set voltage is applied, preventing overvoltage from being applied to the load. The voltage at which the overvoltage protection function of the TCKE6 series operates has hysteresis V_{IN_OVhys}. V_{IN} The overvoltage protection threshold is common to all products, and regardless of whether it is auto-retry or latch type, the IC recovers when the voltage drops below a certain level. An example of the overvoltage protection operation of the TCKE6 series is shown in Figure 6.1.

Table 6.1 OVLO specifications shown in Datasheet

Item	Symbol	Measurement conditions	T_a = 25 °C			T_a = -40 to 125 °C		Unit
			Min	Typ.	Max	Min	Max	
VIN overvoltage protection (OVLO) threshold	V_{IN_OVLO}	—	—	32.0	—	30.0	34.0	V
VIN Overvoltage Protection (OVLO) Hysteresis	V_{IN_OVhys}	—	—	0.9	—	—	—	V

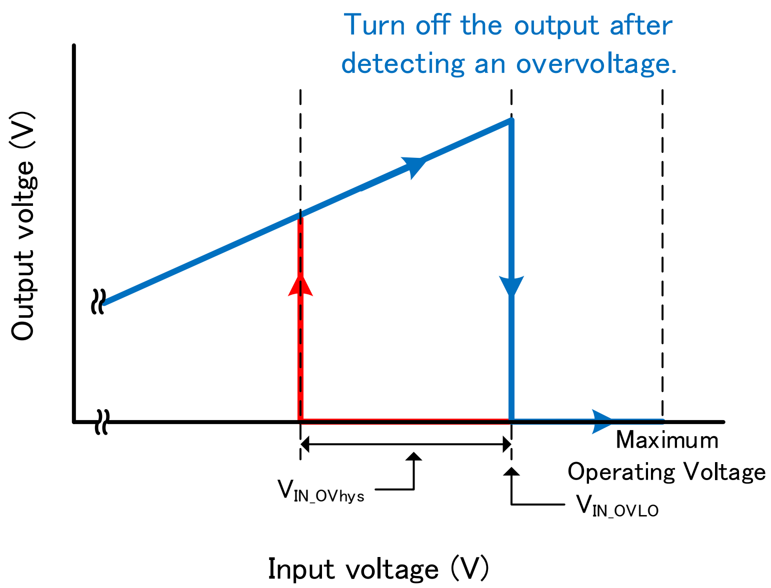

Figure 6.1 Example of detection by OVLO circuit

6.3. Operation of the undervoltage lockout (UVLO) circuit

If the input voltage V_{IN} drops below the minimum operating voltage of the downstream IC or circuit connected to the output terminal VOUT, the undervoltage lockout circuit prevents system malfunction. When V_{IN} rises to $V_{IN} \geqq V_{IN\_UVLO}$, the IC starts operating. The undervoltage lockout circuit has hysteresis V_{IN_UVhys} set, and when V_{IN} falls below a certain voltage, the output automatically turns off. An example of the undervoltage lockout operation of the TCKE6 series is shown in Figure 6.2.

Table 6.2 UVLO specifications shown in Datasheet

Item	Symbol	Measurement Conditions	T_a = 25 °C			T_a = -40 to 125 °C		Unit
			Min	Typ.	Max	Min	Max	
VIN Low Voltage Malfunction Prevention (UVLO) Threshold	V_{IN_UVLO}	—	—	4.0	—	3.6	4.4	V
VIN Undervoltage lockout (UVLO) hysteresis	V_{IN_UVhys}	—	—	0.13	—	—	—	V

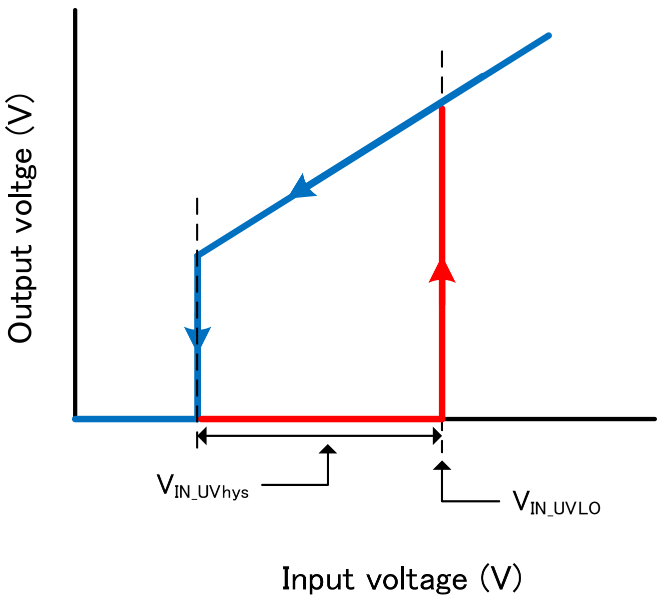

Figure 6.2 Example of detection by UVLO circuit

6.4. Operation of the overtemperature protection circuit (TSD)

The overheat protection circuit (TSD: Thermal Shutdown) is a circuit that protects the IC by turning off the output when a large current continues to flow to the output or when the output is short-circuited(short), causing the ambient temperature to rise rapidly and the junction temperature of the TCKE6 series reaches the overheat protection threshold temperature TSD (155 °C typ.) or higher. At this point, the output is turned off to protect the IC. In the TCKE6 series, when overheat protection is activated, the output is turned off and at the same time, the FLAG terminal output also changes from High level to Low level. The operating temperature and recovery temperature of the overheat protection have hysteresis.

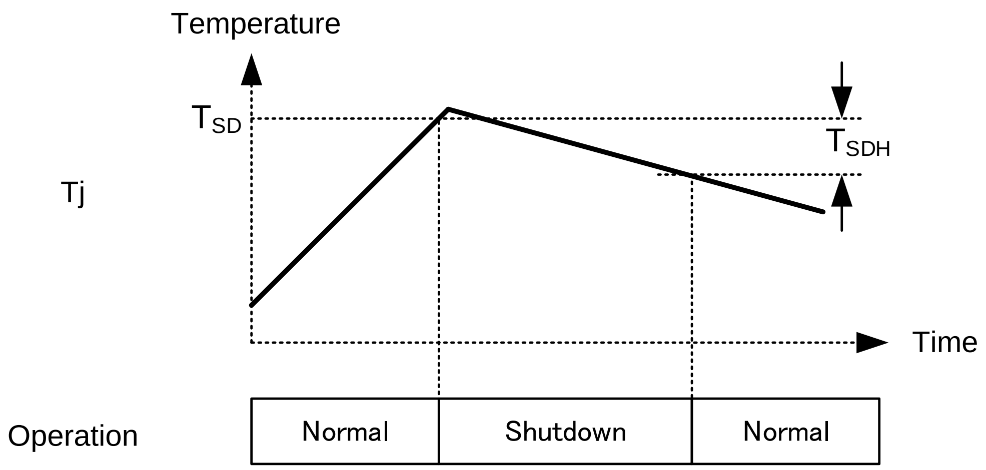

Figure 6.3 Overheat protection circuit operation

6.4.1. Overheat protection with auto-retry type

After transitioning to shutdown state due to overheat protection, the circuit restarts after a certain period (100ms (Typ)).

6.4.2. Overheat protection with latch type

After the overheat protection function operates and transitions to shutdown state, restarting requires a control signal to the EN terminal or reapplying the input voltage, etc. The protection operation continues until restart.

6.4.3. Operating principle of the overheat protection circuit

Detection of junction temperature is performed by comparing the reference voltage VREF, which shows little change in voltage with respect to temperature as shown in Figure 6.4, divided by R_8 and R_9 to produce V_{TSD}, with the forward voltage of the diode. When the TCKE6 series is operating normally, the forward voltage of the diode is higher than VTSD. The forward voltage of the diode has a temperature coefficient of approximately –2 mV/°C, so as the junction temperature rises and the forward voltage drops below V_{TSD}, the comparator inverts, turning off the output of the TCKE6 series. At the same time, the output of the FLAG pin switches from High level to Low level.

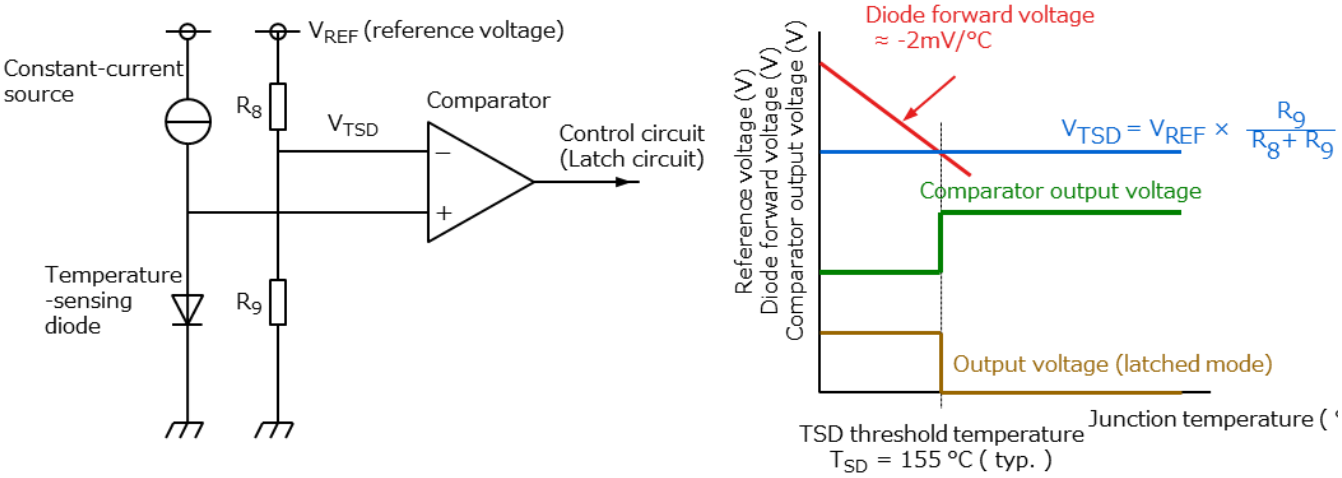

Figure 6.4 Overheat protection circuit and operating principle

Table 6.3 Thermal shutdown T_{SD} specifications shown in Datasheet

V_{IN} = 24 V, R_{ILIM} = 487 Ω, Ta = 25°C

Item	Symbol	Measurement Conditions	T_a = 25 °C			T_a = -40 to 125 °C		Unit
			Min	Typ	Max	Min	Max	
Overheat Protection Threshold Temperature	T_{SD}	T_j	―	155	―	―	―	°C
Overheat Protection Hysteresis Temperature	T_{SDH}	T_j	―	15	―	―	―	°C
Overheat Protection Auto-Retry Interval Time	$t_{TSD, RST}$	Auto-Retry Type Only	―	100	―	―	―	ms

6.5. Operation of overcurrent protection (OCL)

The overcurrent protection circuit is a circuit that suppresses power consumption when an overcurrent flows to prevent deterioration and destruction of the IC and load. When abnormalities or short circuits occur in the load, and the output current output detection current I_{LIMP} exceeds, the output limit current I_{LIM} is restricted, and the output voltage is lowered so that the power consumed by the IC and load is limited. Together with the short-circuit protection circuit described later, double protection against overcurrent is possible, greatly contributing to the prevention of ignition and smoke. Figure6.5 shows the relationship between output voltage and current during output current limiting operation of the TCKE6 series.

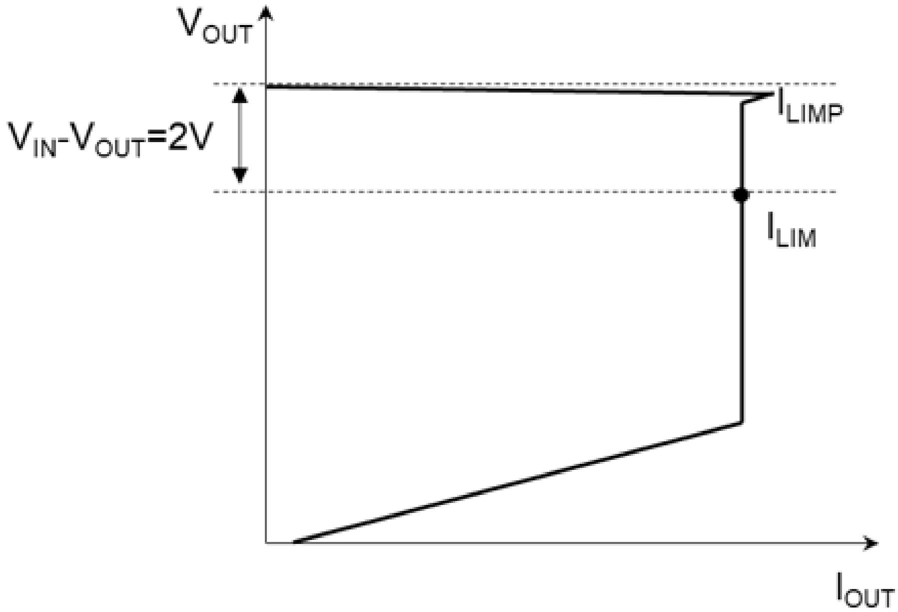

Figure 6.5 Output Voltage-Current Characteristics During Overcurrent Protection Operation

6.5.1. Overcurrent protection operation of the auto-retry type

When the output current value I_{LIMP} is exceeded and overcurrent is detected, the output current is limited to I_{LIM}. Currently, the output voltage decreases according to the relationship between output voltage and current. If the overcurrent is not resolved at this stage, the temperature of the IC rises, and if it reaches the overheat protection temperature, the output stops and transitions to shutdown state. In the case of the auto-retry type, operation resumes after a certain period, but if the overcurrent is still present, the current is limited again. Therefore, the cycle of current limit → temperature rise → overheat protection → shutdown → temperature drop → restart → current limit is repeated in attempts to recover.

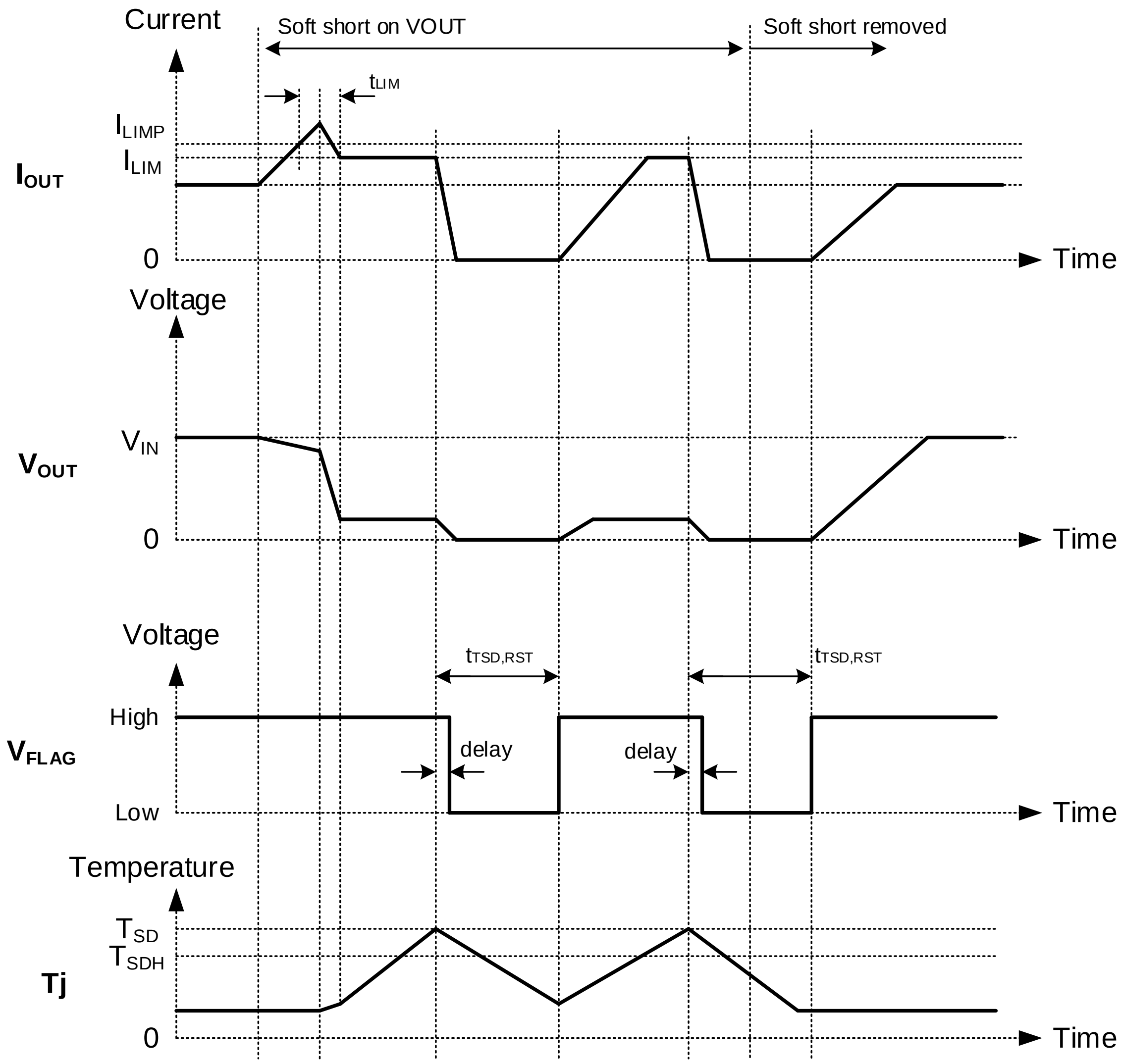

Figure 6.6 Overcurrent Protection Operation Example (TCKE601RA) (Auto-Retry Type)

6.5.2. Overcurrent protection operation of the latch type

Similar to the auto-retry type, when the output current value I_{LIMP} exceeds and overcurrent is detected, the output current is limited to I_{LIM}. Currently, the output voltage decreases according to the relationship between output voltage and current. If the overcurrent is not resolved at this stage, the temperature of the IC rises, and if it reaches the overheat protection temperature, the output stops and transitions to shutdown state. In the case of the latch type, the latch is activated during overheat protection operation, so to restore operation, the EN terminal control signal or reapplication of V_{IN} is required to restart, and the protection operation continues until restart.

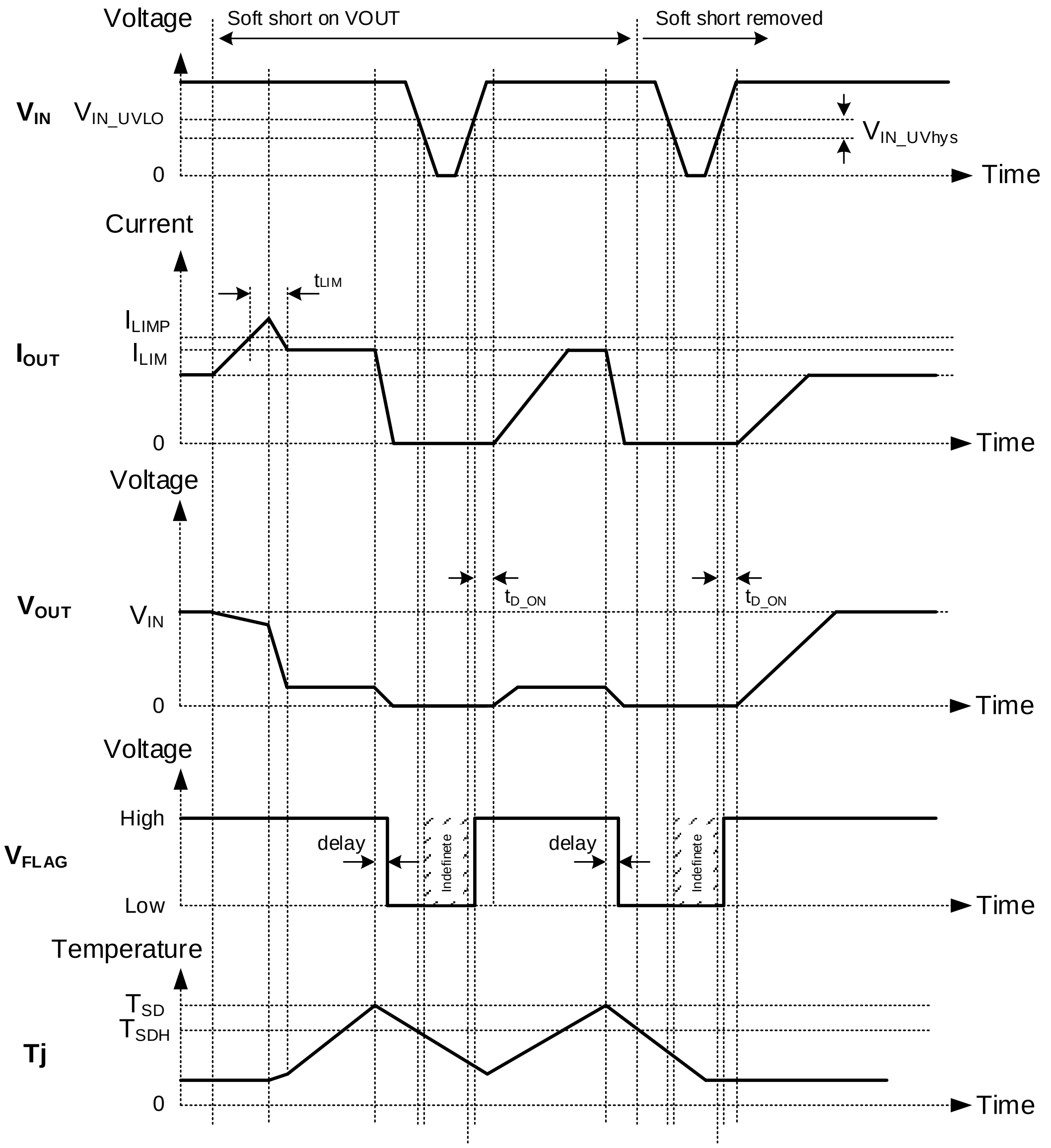

Figure 6.7 Overcurrent Protection Operation Example (TCKE601RL) (Latch Type)

6.5.3. Overcurrent protection circuit settings

The output detection current of the TCKE6 series ILIMP is adjustable, and by appropriately selecting the external resistor RILIM for the ILIM terminal, you can set the optimal current limit value according to the application. ILIMP is (6-3) determined by the formula but be sure to check with the actual device when selecting the resistor value. Also, make sure that RILIM does not fall below 5 kΩ.

$$R_{ILIM} = \frac{29275}{I_{LIMP}+0.0374} \quad (\Omega) \qquad (6-3)$$

I_{LIMP}	:	Output detection current	(A)
R_{ILIM}	:	ILIM Terminal external resistance value	(Ω)

Figures 6.8 and 6.9 show the peripheral circuit diagram of the ILIM terminal and the relationship between I_{LIMP} and R_{ILIM}.

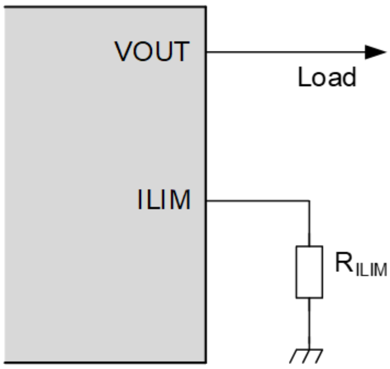

Figure 6.8 ILIM terminal peripheral external circuit

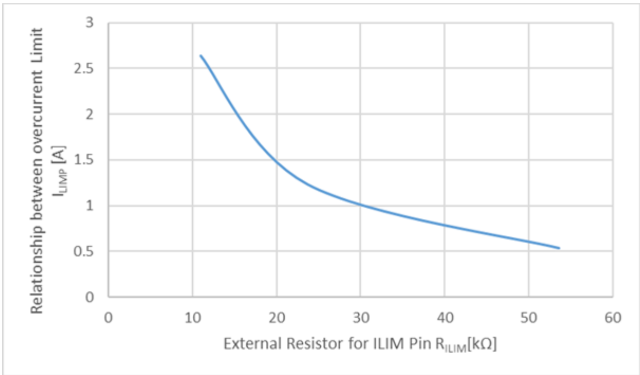

Figure 6.9 I_{LIM} - R_{ILIM} Characteristics Example

Table 6.4 Overcurrent protection (OCL) specifications shown in Datasheet

V_{IN} = 24 V

Item	Symbol	Measurement Conditions	T_a = 25 °C			T_a = -40 to 125 °C		Unit
			Min	Typ.	Max	Min	Max	
Output limit current (Note1)	I_{LIM}	R_{ILIM} = 11 kΩ, $V_{IN} – V_{OUT}$ = 2 V	–	2.40	–	1.84	2.98	A
		R_{ILIM} = 23.7 kΩ, $V_{IN} – V_{OUT}$ = 2 V	–	0.96	–	0.65	1.36	A
		R_{ILIM} = 53.6 kΩ, $V_{IN} – V_{OUT}$ = 2 V	–	0.35	–	0.18	0.57	A
		R_{ILIM} = Open, $V_{IN} – V_{OUT}$ = 2 V	–	0.06	–	–	–	A
Output detection current (Note1)	I_{LIMP}	R_{ILIM} = 11 kΩ	–	2.70	–	2.06	3.26	A
		R_{ILIM} = 23.7 kΩ	–	1.28	–	0.90	1.72	A
		R_{ILIM} = 53.6 kΩ	–	0.58	–	0.32	0.96	A
		R_{ILIM} = Open	–	0.19	–	–	–	A

Note1 : Design guarantee value

6.6. Operation of the short-circuit protection circuit

The short-circuit protection circuit is a circuit that stops operation when the power supply line or load is short-circuited due to some abnormality, preventing excessive current from flowing. In the TCKE6 series, if the output current reaches the output limit current I_{LIM} 1.9 times (typ.) within a very short period, the circuit judges it as a short-circuit and activates this protection circuit. The TCKE6 series adopts ultra-fast short-circuit protection circuit technology (Fast trip circuit), and from the occurrence of a short-circuit, t_{SHORT} (see Figure 6.10: 1 μs (typ.)) the protection circuit can be activated.

6.6.1. Auto-retry type VOUT short-circuit protection operation

When the VOUT terminal is short-circuited and the output current reaches the output limit current I_{LIM} 1.9 times, VOUT is judged as short-circuited, and output is stopped. After that, operation resumes with a soft start, but if the VOUT voltage remains below the short-circuit judgment voltage (1.7 V (typ.)), continues and if judged as VOUT short-circuit, it transitions to shutdown state. After a certain period, operation resumes, but if the VOUT short-circuit is not resolved, it shuts down again. The auto-retry type repeats this recovery attempt in this way.

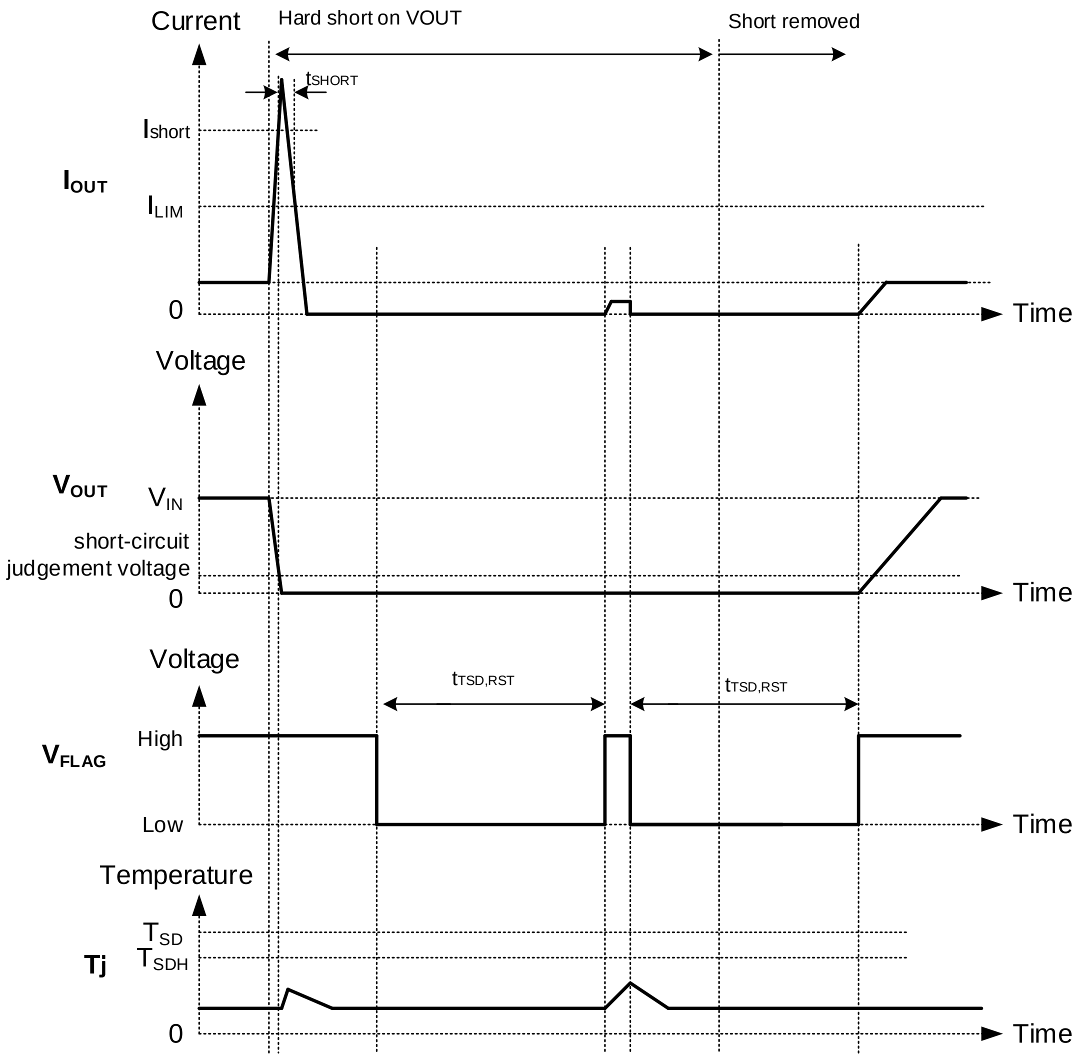

Figure 6.10 Short-circuit protection and overcurrent protection Operation example (TCKE601RA) (Auto-retry type)

6.6.2. Latch type VOUT short-circuit protection operation

Similar to the auto-retry type, VOUT terminal is short-circuited, and when the output current output limit current I_{LIM} reaches 1.9 times, VOUT is judged as short-circuited and the output is stopped. After that, operation resumes with soft start, but if the VOUT voltage remains at or below the short-circuit judgment voltage of 1.7 V (typ.), continues to be judged as VOUT short-circuit, and transitions to shutdown state. To recover, unlike the auto-retry type, EN terminal control signal or reapplication of VIN is required to restart. Protection operation continues until restart.

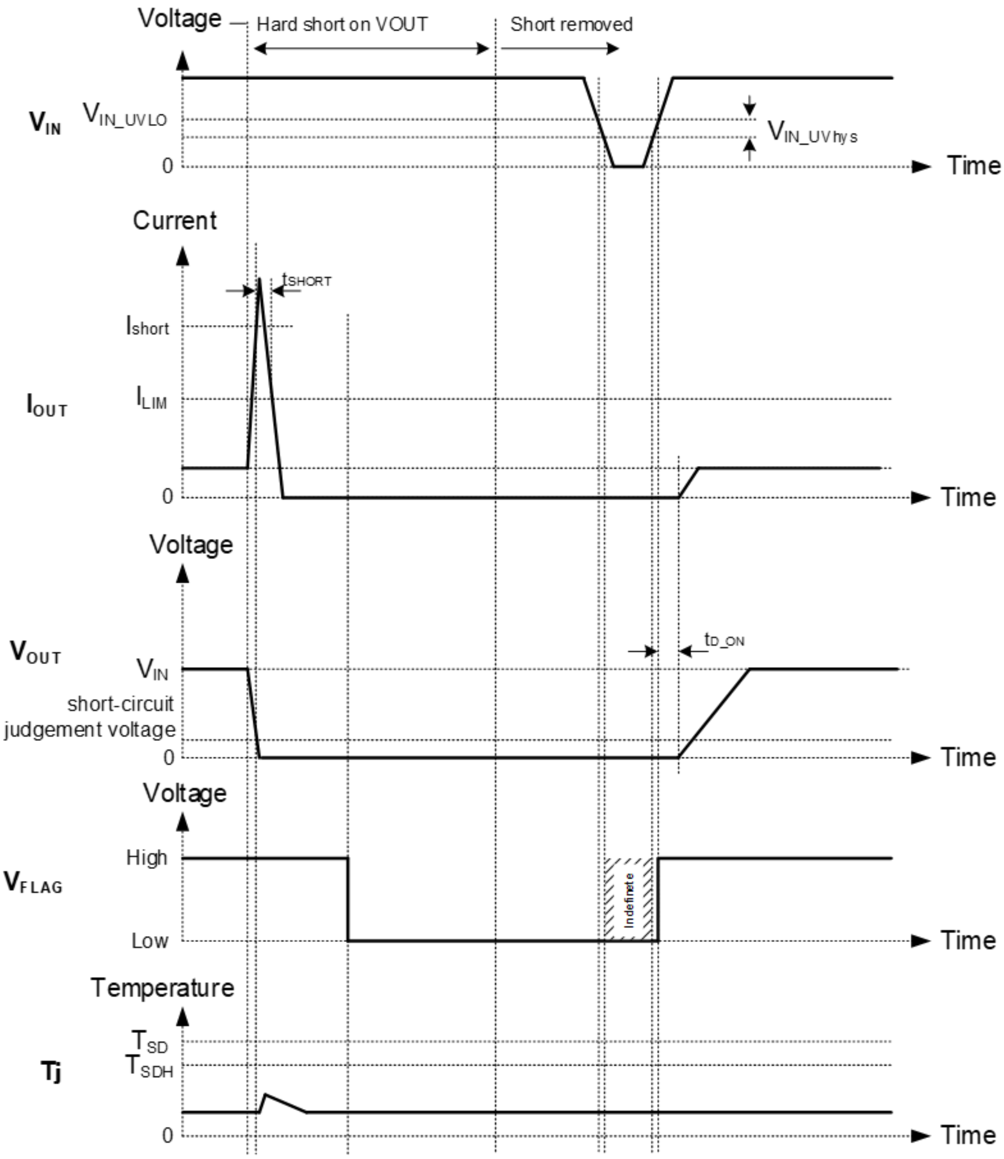

Figure 6.11 Short-circuit protection and overcurrent protection Operation example(TCKE601RL) (Latch type)

6.7. Slew rate control function (inrush current suppression function) operation

When the output is turned on, an inrush current flows to charge the capacitor connected to the load side. If this current is too large, the overcurrent protection circuit operates, making it impossible for the output to rise, or causing input voltage to undershoot and output voltage overshoot. To prevent these, the slew rate during output voltage rise is controlled to limit the inrush current; this is the inrush current suppression circuit. The output rise time tr of the TCKE6 series is fixed at 150µs (Typ.). Figure 6.12 shows, using this circuit, the output voltage rise and inrush current waveforms when the inrush current is limited. Figure 6.13 shows the output voltage rise and inrush current waveforms when power is applied to the TCKE601RL.

TCKE603RL, V_{IN} = 24 V, EN = L to H, C_{OUT} = 1 µF, Ta = 25°C

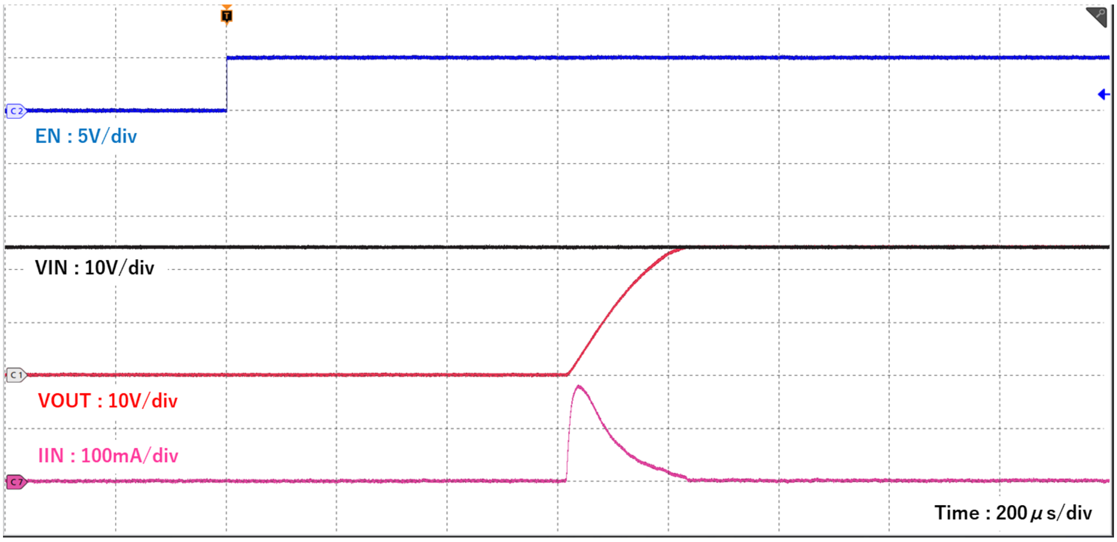

Figure 6.12 Slew rate control function circuit operation waveform

TCKE601RL, V_{IN} = 24 V, C_{OUT} = 1 µF, Ta = 25°C

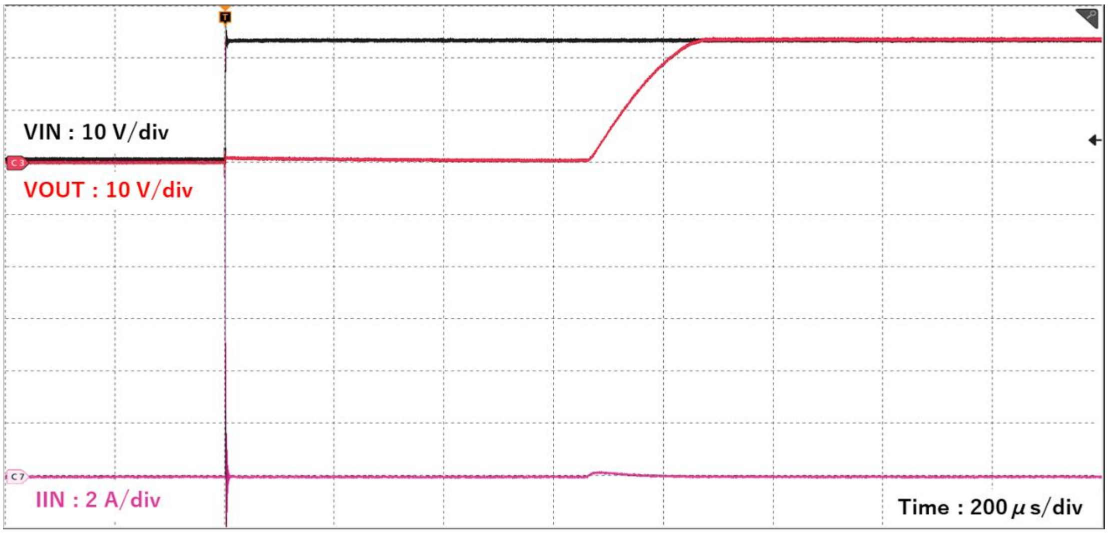

Figure 6.13 Slew rate control function at power-on circuit operation waveform

6.8. FLAG terminal (TCKE601RA/TCKE601RL only)

TCKE601RA/TCKE601RL has FLAG function. The FLAG circuit outputs a diagnostic signal to the outside of the IC when overvoltage protection, short-circuit protection, overheat protection, or undervoltage lockout is activated, changing the FLAG terminal output from High to Low to indicate that a system abnormality has occurred. The FLAG terminal has an open-drain structure, so please use it with an external pull-up resistor (Figure 6.14).

Please select the pull-up resistor for the FLAG terminal after fully considering the sink current (maximum rating). As a reference, 10 kΩ is recommended. Also, after thoroughly evaluating with the actual device, please determine the appropriate resistor value.

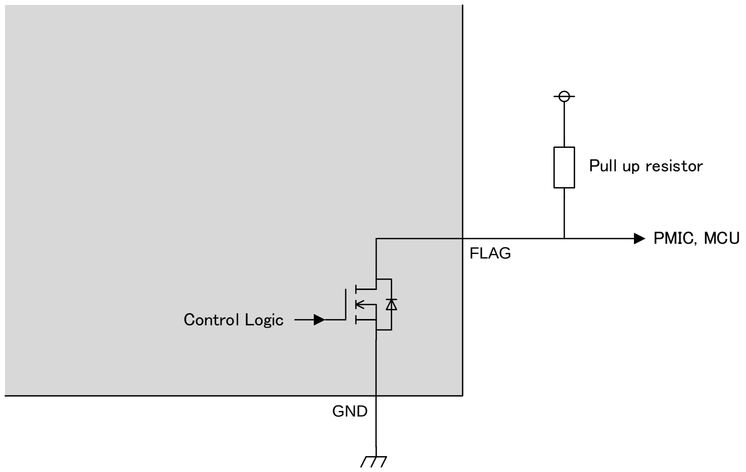

Figure 6.14 FLAG Terminal equivalent circuit

Table 6.5 FLAG Output target functions and operation

Abnormal mode	FLAG Output	IC Operation
Over temperature	Yes	Shutdown
VIN Over voltage	Yes	Shutdown
VIN Under voltage	Yes (Note2)	Shutdown
IOUT Over current	—	I_{OUT} current limiting
VOUT short circuit	Yes	Shutdown
ILIM pin short	—	Shutdown

Note2: If V_{IN} falls below the internal operating voltage (2.2 V (Typ.)), FLAG will not be output.

6.9. MODE terminal (TCKE602RM only)

In TCKE602RM, by switching the MODE terminal, you can change the recovery mode. When a High level input is applied, the recovery operation type becomes auto-retry type, and when a Low level input or open is applied, the recovery operation type becomes latch type. The on/off threshold voltage of the MODE terminal has hysteresis, so please set the control signal High level to 1.1 V or higher, and the Low level to 0.4 V or lower. Please do not switch the MODE terminal while the IC is operating.

6.10. EN terminal (TCKE603 only)

TCKE603RA/TCKE603RLis equipped with an EN terminal, and you can control the operation of the TCKE6 series using this terminal. Please directly input a control signal from outside to the EN terminal (see Fig.6.15). The ON/Off threshold voltage of the EN terminal has hysteresis, so set the control signal's High level to 1.1 V or higher, and the Low level to 0.4 V or lower.

Additionally, TCKE603RA/TCKE603RA's EN terminal has a window comparator connected as shown in

Fig. 6.16. The window comparator has two threshold values, V_{REF_P} and V_{REF_N}, so even if an unstable control signal with superimposed chattering or ringing is input, you can obtain a stable output as shown in Fig. 6.17(b). In contrast, with a standard inverter that has only one threshold for the input, the output may malfunction as shown in Fig. 6.17(a).

Note thatTCKE603RA/TCKE603RA has a built-in pull-down resistor R_{EN} inside the IC, and when the EN terminal is open, EN is controlled to the Low level.

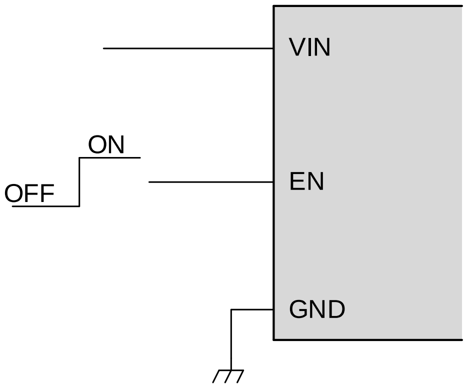

Figure 6.15 Example of EN terminal connection (external control)

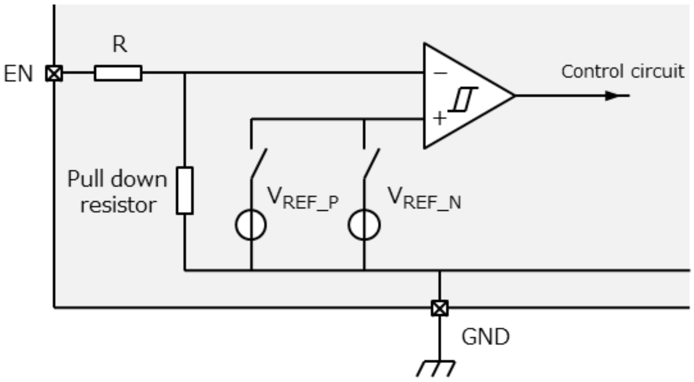

Figure 6.16 EN Terminal Equivalent Circuit

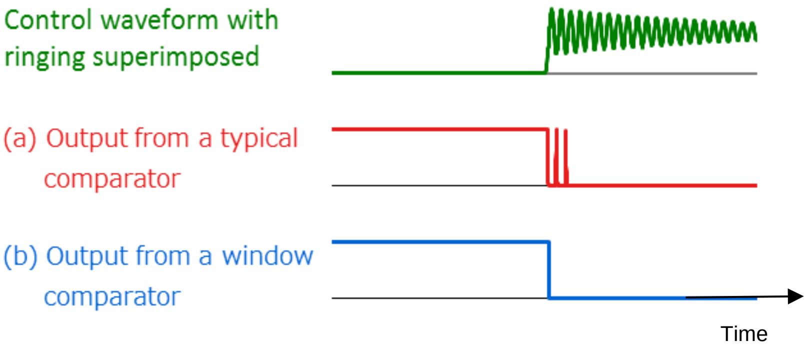

Figure 6.17 Operation of standard comparator and window comparator

6.11. Output discharge function

The TCKE6 series has a discharge resistor R_{DIS} inside the IC, which discharges the output capacitor when the IC is turned off. Figure 6.18 shows the output discharge waveform of the TCKE6 series. When the IC turns off, the internal discharge MOSFET turns on and brings the output voltage to 0 V. In its initial state, the discharge MOSFET operates in the saturation region and performs constant current discharge. After that, when this MOSFET enters the linear region, it switches to resistive discharge.

V_{IN} = 24 V, EN = H to L, C_{OUT} = 1 μF, R_{OUT} = 1 kΩ, Ta = 25 °C

V_{IN} = 24 V, EN = H to L, C_{OUT} = 10 μF, R_{OUT} = 1 kΩ, Ta = 25 °C

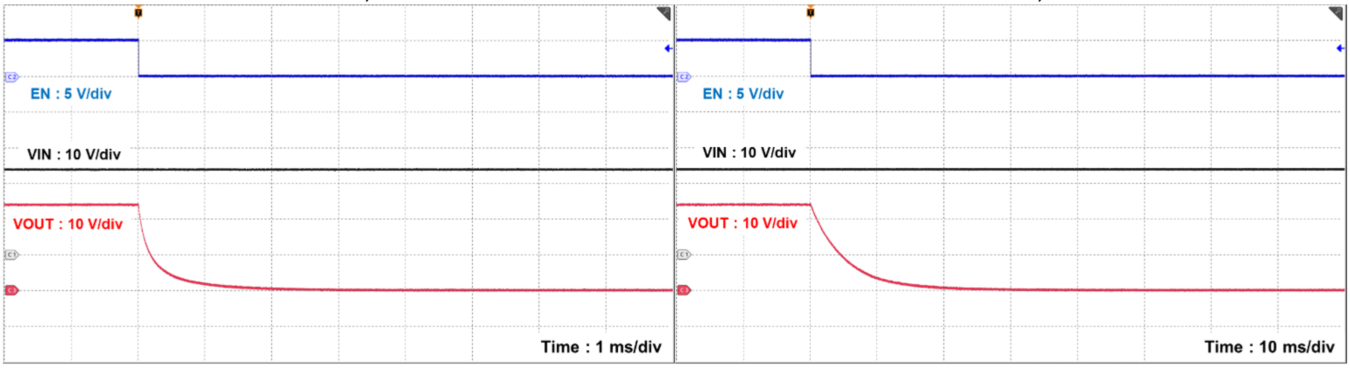

Figure 6.18 Output discharge waveform

7. Application examples of the TCKE6 series

Below are some application examples.

- Robot Cleaner

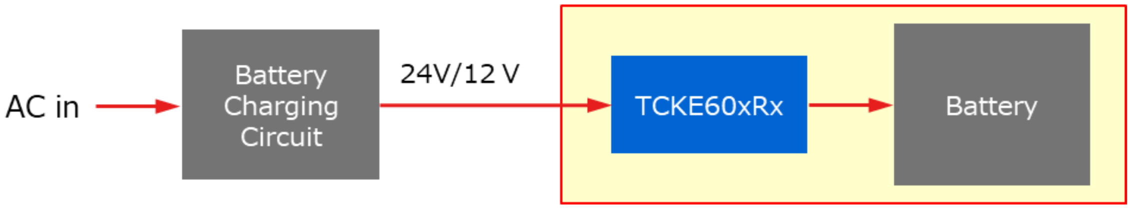

Figure 7.1 Application to robot cleaner

- Commercial Printer

Figure 7.2 Application to commercial printer

8. Precautions for use

If you use this product with a non-capacitive load at startup, please pay attention to the following points.

- When starting up this IC, make sure that the load current is below the output current limit I_{LIM}.
- When Ta = -10° C or lower, please apply current after V_{OUT} rises by at least 100 mV, and then bring up V_{OUT}.

- About input/output capacitors

This product can use ceramic capacitors, but depending on the type, some may have very large temperature characteristics. When selecting capacitors, please fully consider the operating environment. If the output capacitor is large, the inrush current may cause heating and activate the IC's overheat protection function, preventing output startup, so always check with the actual device. Please confirm.

- About mounting

If the distance between the IC and the input/output capacitors is long, the impedance of the wiring resistance and the L component may affect phase compensation. To achieve a more stable power supply, mount the input/output capacitors as close to the IC as possible, and make the VIN and GND patterns as large as possible to minimize wiring impedance.

- About allowable loss

In actual use, please design the board pattern with as much margin as possible for the expected maximum allowable loss. Also, when using the product, please consider parameters such as ambient temperature, input voltage, and output current, etc. and design with appropriate derating for the maximum allowable loss.

- About protection circuits

This product is equipped with overcurrent and overheat protection circuits, but it does not guarantee that the device will always operate within the absolute maximum ratings. Depending on usage conditions, there may be an impact on product specifications or reliability guarantees. When using this device, please consider the above and the derating for absolute maximum ratings described in our "Semiconductor Reliability Handbook", etc., and ensure that the absolute maximum ratings are never exceeded under any circumstances. Also, we recommend implementing sufficient safety measures such as fail-safe in the set, etc..

9. Summary

Up to this point, we have described how to use the TCKE6 series and basic protection features. The TCKE6 series not only interrupts large currents but can also protect IC and devices from various abnormal conditions such as overvoltage and overheating. In addition, it is equipped with convenient functions such as inrush current suppression and malfunction prevention during low voltage. These features greatly contribute to improving the reliability of electronic devices. We hope you will make use of the TCKE6 series with reference to this document, and achieve higher performance, miniaturization, and total cost reduction for your equipment.

- eFuse IC product page is here → Click Here
- eFuse IC parametric search is here → Click Here
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