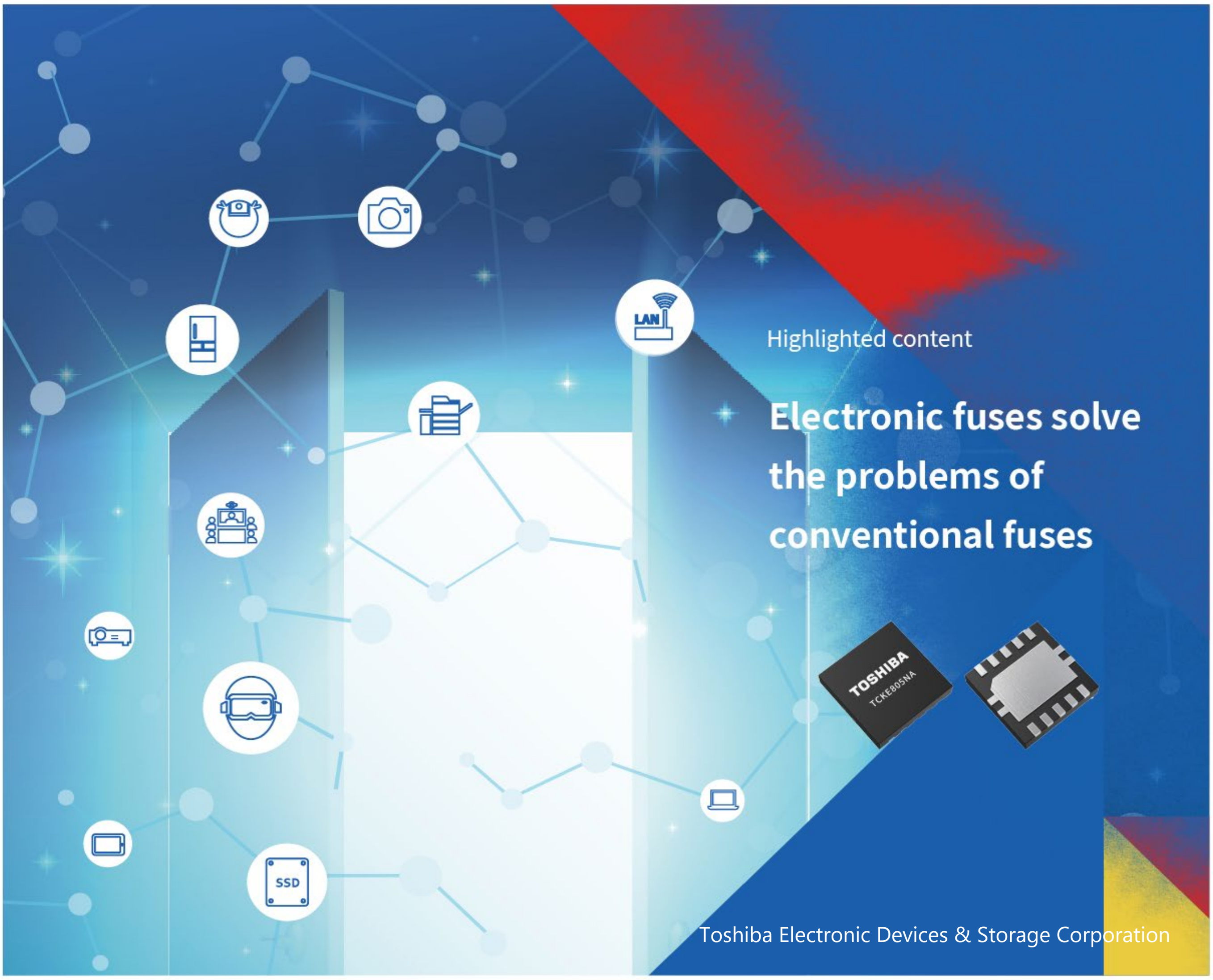



In recent years, electronic fuses have attracted considerable attention and the industry's need for solutions of this kind is continuously increasing. Conventional glass tube fuses, chip fuses and poly fuses are easily affected by ambient temperatures and other usage conditions, and the accuracy of the breaking current is low. In addition, the speed of response is slow. The impact of these issues has intensified in recent years because of the miniaturization of electronic systems and the need to improve performance of systems. Another important factor to consider is that conventional fuses must be repaired or replaced after they have blown. Moreover, fuses are now required to have more advanced functions in order to comply with IEC62368-1 - the new safety standard relating to ICT and AV equipment.

Electronic fuses are integrated circuits (ICs). Here MOSFETs are used for voltage-current detection circuits, control circuits, and current path interruptions. Because they are ICs, they integrate high-precision and high-speed functions within compact packages. These cover overcurrent, overvoltage, short-circuit, overheating, etc.. Whereas conventional fuses basically only shut down the current path, electronic fuses are able to offer many protection and control functions, thereby making it relatively straightforward to obtain IEC62368-1 certification. Electronic fuses are able to overcome the issues that are associated with conventional fuses.

Content links

# Why are electronic fuses attracting attention?

Why have electronic fuses been attracting attention recently?

With recent improvements in equipment performance and the need to comply with new safety standards, the deficiencies of conventional fuses have become more apparent.Electronic fuses with excellent performance and various protection functions are receiving a lot of attention. Electronic fuses are also called semiconductor fuses, as they are actually ICs. Toshiba calls its electronic fuses eFuse ICs.

To be honest, I only recognize that fuses are parts that prevent smoke and ignition when an overcurrent flows through a power source. Is that still correct?

The basic role of fuses is exactly what you have described, but there are several types of fuses used in electronic circuits, and their characteristics are different. The characteristics of typical fuses used in electronic circuits can be briefly summarized as follows.

| | **Electronic fuse** **Toshiba eFuse IC** | Poly fuse (Poly switch / Resettable fuse) | Chip fuse | Glass tube fuse |
|---|---|---|---|---|
| Protection method | **Shut down by MOSFET switch** | Current limit by resistance increase | Blown conductive part | Blown conductive part |
| Protection speed | **150 ns (typ.)** | Several 100 ms to several s | Several s | Several s |
| Repeated use | **Possible** | Possible | Not possible | Not possible |

* Example of TCKE8xx series. Speeds may vary by product.

Typical examples other than electronic fuses are poly fuses, chip fuses, and glass tube fuses. Poly fuse is also sometimes called poly switch or resettable fuse. The first major difference between these is that they can be used repeatedly or not. Chip fuses and glass tube fuses cannot be used repeatedly because they provide protection by fusing the conductive part. However, electronic fuses and poly fuses can be used repeatedly. In addition, electronic fuses are characterized by the high speed protection.

So electronic fuses can be used repeatedly and their reaction times are overwhelmingly faster - is that correct?

That's right. Electronic fuses, I'll call them eFuse ICs from here on, have a big advantage that differentiates them from other fuses. That's what is now making them so appealing.

## Three major benefits of eFuse IC

What are the advantages of the eFuse IC that cannot be achieved with a conventional fuse?

Three major benefits of eFuse IC are below.

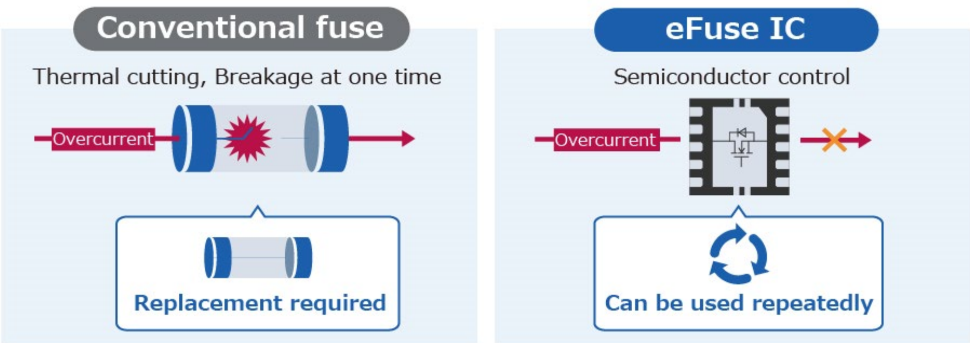
Benefit 1: eFuse ICs can be used repeatedly due to their semiconductor structure
Benefit 2: Superior protection performance compared to conventional fuses
Benefit 3: Reduced certification work for IEC62368-1, a new safety standard*
* This includes the eFuse IC to be certified.

### Benefit 1: eFuse ICs can be used repeatedly due to their semiconductor structure

I think you already have an idea of the first benefit, “it can be used repeatedly”. Of the conventional fuses, chip fuses and glass tube fuses can never be used again because the conductive part blows, or is destroyed, when they are interrupted for protection. On the other hand, eFuse is a semiconductor IC, and its shutdown operation is realized by turning on and off the built-in MOSFET, so it can be used repeatedly. Can you see what an advantage this would be?

I think the term "interruption" means "blowing a fuse" as we often say. When a fuse blows, we have to replace it with a new one, right?

Exactly. But replacing a part is quite a challenge, because you have to consider not only the cost of the part to be replaced, but also the work and time involved. The eFuse doesn't need to be replaced, so the advantage is that we can save money and time on that.



Benefit 2: Superior protection performance compared to conventional fuses

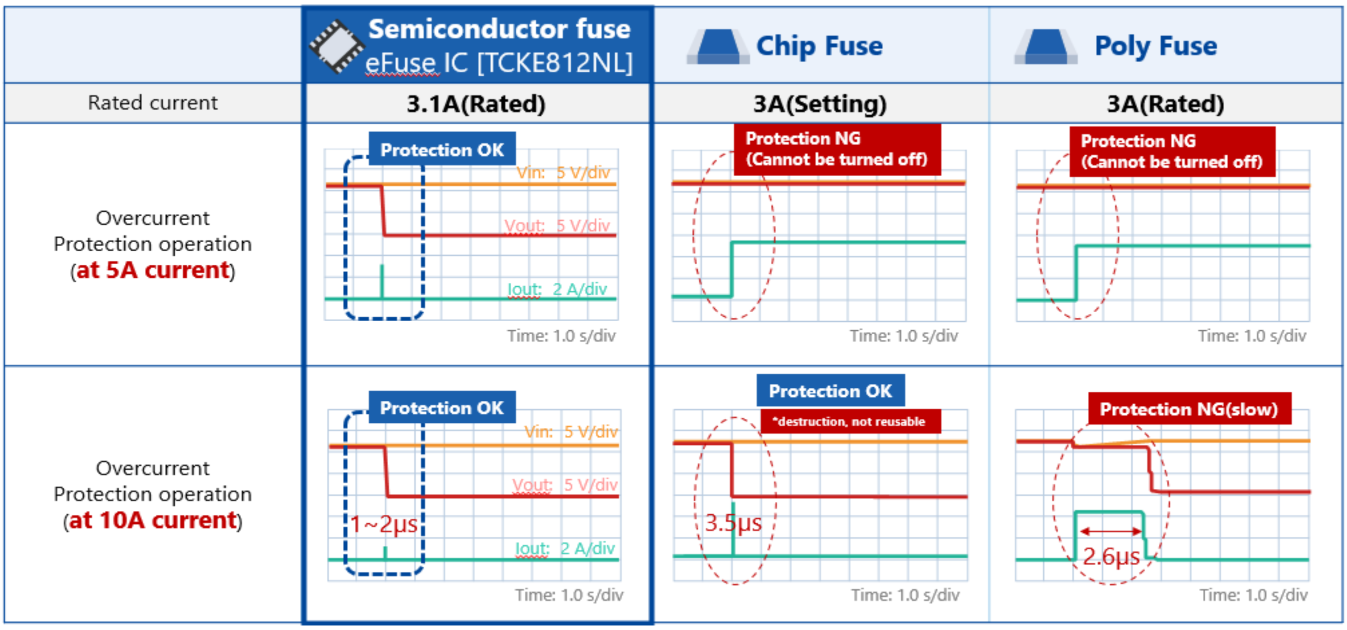
The second benefit “Superior protection performance compared to conventional fuses” means that the fuse has a number of protective functions that cannot be achieved with a conventional fuse alone. This is possible because eFuse is an IC. Here's a diagram that summarizes the comparison.

| | **Semiconductor fuse** eFuse IC | Glass tube Fuse | Chip Fuse | Poly Fuse |
|---|---|---|---|---|
| Repeatability | ✓ | — | — | ✓ |
| Overcurrent protection speed and accuracy | ✓ | — | — | — |
| Other protection feature (Short, Overvoltage, Rush current, Thermal) | ✓ | — | — | — |
| Temperature variation | ✓ | — | — | — |
| Mount area | ✓ | — | ✓ | — |
| Whole protection circuit area | ✓ | — | — | — |
| Unit cost | ✓ | ✓ | ✓ | — |
| Total system cost | ✓ | — | — | — |

Besides being able to be used repeatedly, eFuse has incomparably better speed and accuracy in overcurrent protection, which is the basic function of a fuse. It also has other protection features physical fuses do not have. Each protection function will be explained in detail later.

As you mentioned in your reasons for focusing on "speed of protection," how much of a difference does it make?

I will explain you using a waveform diagram comparing the speed and accuracy at which overcurrent protection works, which is the basic function of a fuse, below.




Do you make sense that the overcurrent protection, it is expected to provide protection by quickly shutting down when the set current limit of eFuse is exceeded. and other fuses, if the rated value is exceeded?
The chart above compares the operation of a 5A and 10A overcurrent under the 3A setting/rating. First, we can see that at 5A, the eFuse IC is quickly interrupting the current, but the poly fuse and chip fuse are not activating the interruption because the current is still flowing. Both products finally shut down when the current flows up to 10A, but the time slows to protection.

That's just under twice the rated value. I think it's pretty wide.

That's basically what conventional fuses are. In contrast, eFuse has a very high current accuracy at which the protection is activated.

By the way, Figure 3 shows that chip fuse is more advantageous than eFuse in terms of "single mounting area" and "component unit cost", isn’t it?

In terms of the mounting area of individual components, eFuse is currently slightly larger than the chip fuse, and the cost of individual components is also in favor of the chip fuse. However, it is important to think about size and cost in "total" terms.

Do you mean "Total Mounting Area" or "Total Cost" in the table? It is true that eFuse IC has a huge advantage in those areas, but what exactly does it mean?

"Total xxx" is the idea of comparing the mounting area and cost on the premise that the functions and performances of the comparisons are the same, for example. The eFuse IC has many built-in protection functions shown in the figure, but to implement the same functions when using other fuses, we need to design and add protection circuits using ICs and necessary components. When you consider the mounting area and cost, eFuse IC is much more compact and less expensive.

Understood. Does it mean that we need to look at the total picture rather than simply comparing the size and cost of individual components, isn't it? Then the eFuse IC definitely has the advantages in terms of total cost including functionality, performance, and maintenance.

Exactly.

Benefit 3: Reduced certification work for IEC62368-1, a new safety standard

The last one of three benefits is it reduces certification work for IEC62368-1. You know that parts and equipment need to comply with various national and international standards and certifications, right? The IEC60950-1 safety standards for information and communications equipment and the IEC60065 safety standards for audio-visual equipment have been abolished. IEC62368-1, a new safety standard for information and communication equipment and audio-visual equipment was enforced in December 2020. Therefore, applicable equipment

I've heard that it's a lot of work to do specified tests and certify conformance for obtaining the certification.

That's right. Many certifications require a considerable amount of time and money, such as taking the actual certification exam. However, it is possible to reduce the work involved in obtaining IEC62368-1 certification by using existing certified parts. Please check the data sheet of each product to see if it is certified or not.

## What is eFuse ICs?

So, for an actual eFuse ICs. Toshiba has two types of eFuse ICs "TCKE712BNL" and TCKE8xx Series". Let's take a device from TCKE8xx series. These devices are currently gaining a lot of interest.

Are they complicated devices?

It certainly has many protection functions and is adjustable. However, in a small 10-pin package, the external parts are basically only a few capacitors and resistors.

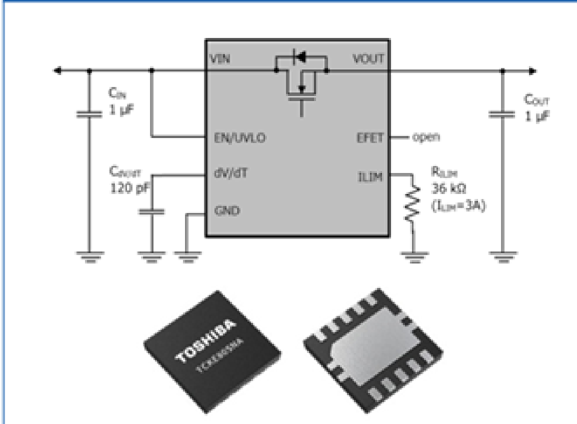
Commentary: Overview of eFuse IC "TCKE8xx series"

The TCKE8xx eFuse IC series can handle up to 18V / 5A, and have overcurrent protection, short-circuit protection, overvoltage clamp, inrush current reduction, and under voltage lockout (UVLO), thermal shutdown, plus an optional reverse current blocking function. The current limit for overcurrent protection can be set via a single external resistor.

| Features | |
|---|---|
| High input voltage | 18.0 V (max) |
| High output current | 5.0 A (DC) |
| Low ON resistance | 28 mΩ (typ.) |
| Adjustable overcurrent limit protection | 5.0 A (max) |
| Built-in fixed overvoltage clamp circuit<br>* Some products do not have overvoltage clamps | 5V power rail = 6.04 V (typ.)<br>12V power rail = 15.1 V (typ.) |

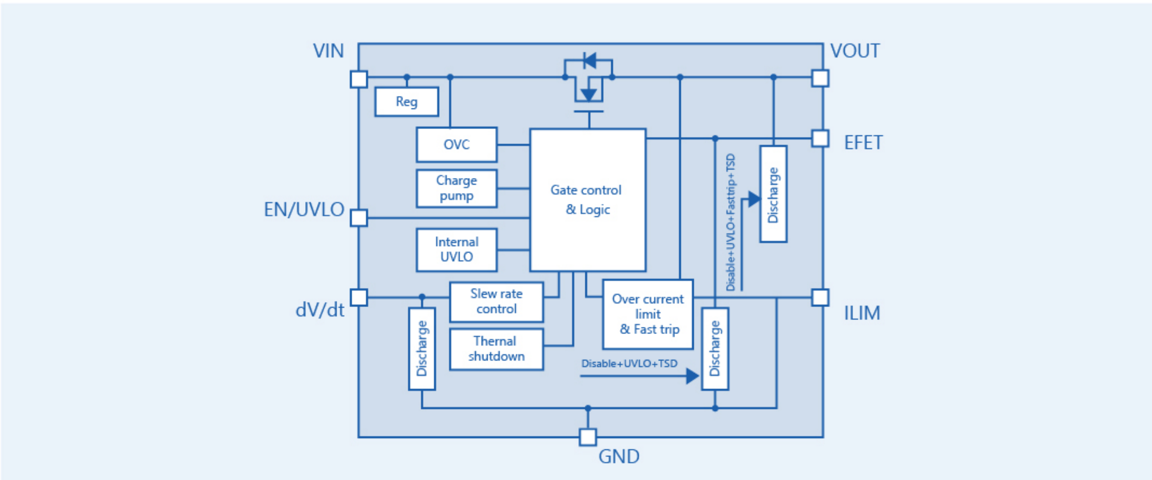
- Built-in inrush current reduction circuit
- Built-in adjustable under voltage lockout circuit
- Supports reverse current blocking function
- Built-in thermal shutdown circuit
- Built-in auto discharge function
- Recovery operation: Two types, auto-retry and latch, are available
- Small package
- IEC62368-1 certified

**eFuse: TCKE8xx series peripheral circuit example**




WSON10B : 3.0 mm x 3.0 mm, t: 0.7 mm (typ.)

eFuse: TCKE8xx series block diagram



| Terminal | Explanation |
|---|---|
| EN/UVLO | This pin has two functions.<br>One function is to enable the output voltage of the internal MOSFET and the EFET terminal.<br>Another function is UVLO function, with adjustable OFF voltage via an external resistor. |
| ILIM | This terminal adjusts the overcurrent limit value.<br>It allows adjustment of the overcurrent limit value with the resistance between the ILIM terminal and the GND terminal. |
| dV/dT | This terminal adjusts the start-up time.<br>The start-up time is adjusted by the capacitance between the dV/dT terminal and the GND terminal. |
| EFET | It is the gate voltage output terminal of the reverse current blocking Nch MOSFET.<br>This should remain open when not using the reverse current blocking function. |
| VIN | Supply Input terminal |
| GND | Ground terminal |
| VOUT | Output terminal |

The TCKE8xx series consists of overvoltage clamp voltage and recovery operation type options. The overvoltage clamp voltage is set according to the system voltage to prevent overvoltage from being applied to the load. There are devices with a clamp voltage of 6.04 V (typ) for the 5 V power rail, ones with a 15.1 V (typ) clamp voltage for the 12 V power rail, as well as ones without the overvoltage clamp function.

There are two types of recovery operation. The auto-retry type will automatically try to recover until the failure is resolved, while the latch type is latched during the thermal shutdown operation and is restored by an external control signal to the EN pin once the failure has been resolved.

A total of six products are available to choose from: overvoltage clamping (three types) and recovery operation type (two types).

| Product name | Overvoltage clamp | VEN/UVLO operation | Recovery operation type | Actual product display | Package |
|---|---|---|---|---|---|
| TCKE800NA | N/A | Active High | Auto-retry | 800NA | WSON10B(3.0mm x 3.0mm,t:0.7mm(typ.)) |
| TCKE800NL | N/A | | Latched | 800NL | |
| TCKE805NA | 6.04V(typ.) | | Auto-retry | 805NA | |
| TCKE805NL | 6.04V(typ.) | | Latched | 805NL | |
| TCKE812NA | 15.1V(typ.) | | Auto-retry | 812NA | |
| TCKE812NL | 15.1V(typ.) | | Latched | 812NL | |

## What are the features of the eFuse IC?

When considering the IC, the first few pages of the datasheet are quite important.

It seems to cover many general things, is it correct?

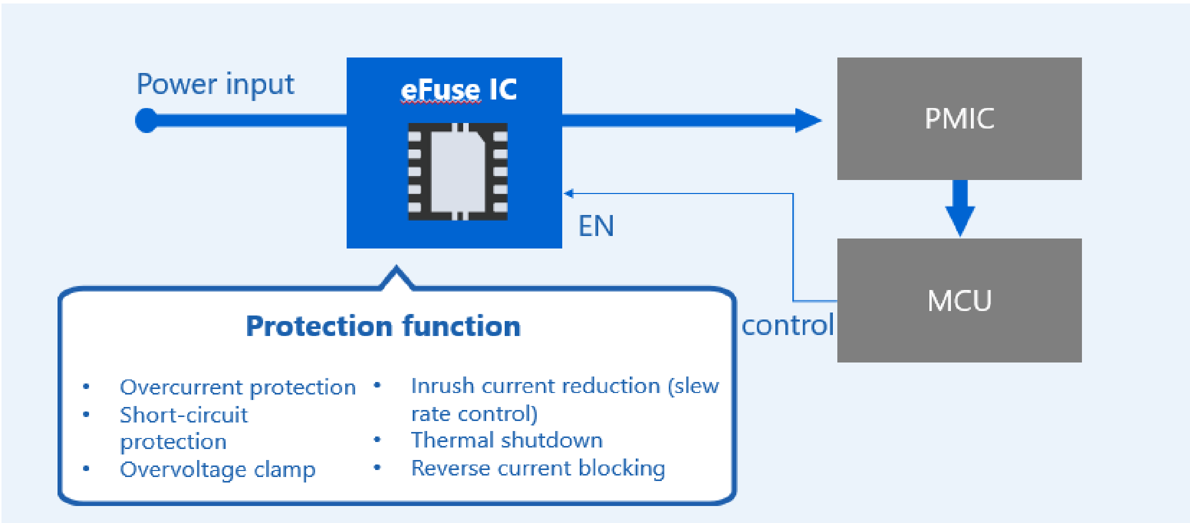
So general topics will be covered there, but when considering the IC, the first page of the datasheet can prove to be important. Physical size, maximum ratings and operating conditions all need to be checked thoroughly.

I see. I'll try to compare them next time.

Now let's explain the protection function that is the key point of eFuse ICs. This level of explanation often starts around the middle of the datasheet.

**Commentary: Key TCKE8xx series protection functions**

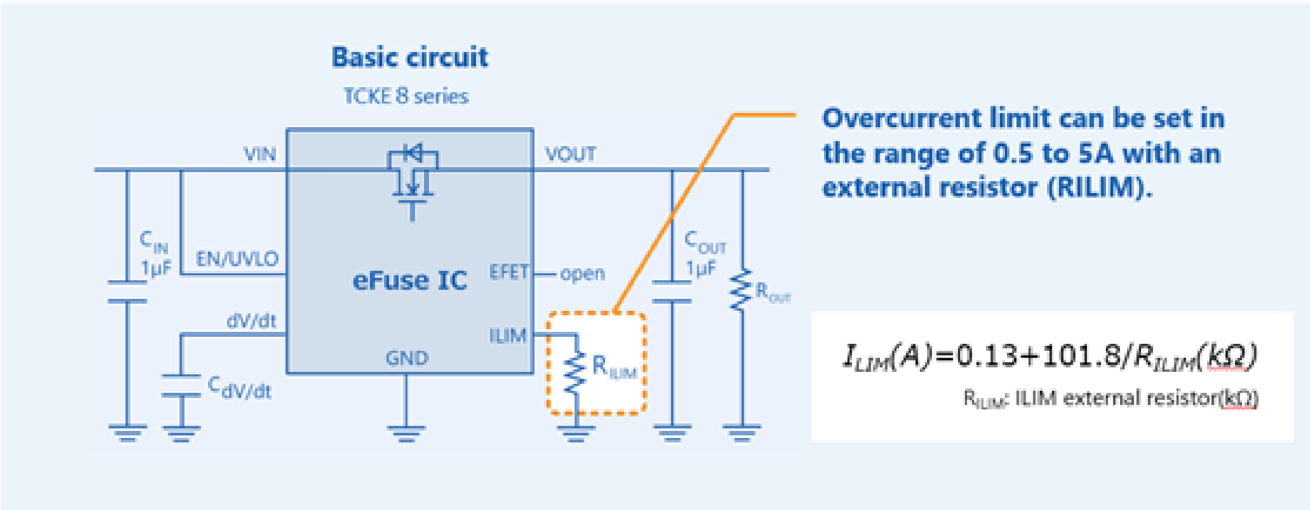
The TCKE8xx series eFuse ICs have the following protection functions. These are intended to safeguard the IC itself and the subsequent stage (load device), in order to reduce the risk of damage. Overcurrent protection, short-circuit protection, and suchlike are functions that detect failure or damage of the load device, preventing smoke, fire, or other forms of damage.



■ Overcurrent protection function

The overcurrent protection function clamps the output current IOUT so that it does not exceed the set limit value when the output current IOUT increases due to an abnormality in the load connected to the VOUT or a short-circuit, preventing momentary interruption of the power supply, while simultaneously protecting against deterioration of the IC itself and the load devices, or damage risks. It also has a short-circuit protection function (described later) that operates when the IOUT substantially exceeds the current limit within a very short time. This means the protection function against overcurrent is double-equipped.

The IOUT limit at which overcurrent protection is activated can be easily set by the external resistor RILIM connected to the ILIM pin. With the TCKE8xx eFuse IC series, this can be set over a wide range of current values, going from 0.5A to 5A. The RILIM value can be set arbitrarily according to the formula, increasing the degrees of freedom for circuit design.

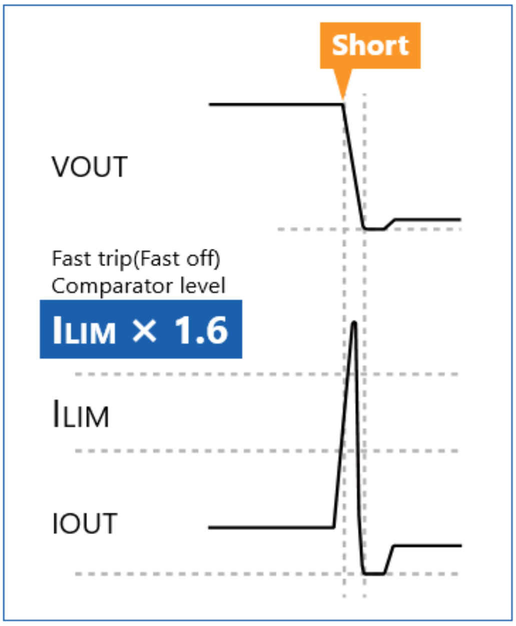


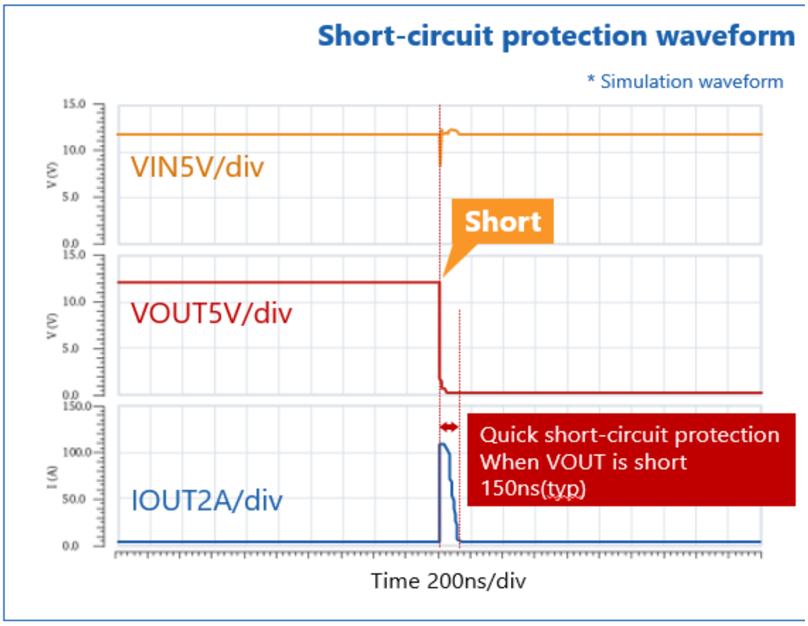

The overcurrent protection is configurable and convenient?

Yes. It will be a function to consider as a set together with the short-circuit protection which will be explained next. Overcurrent increases power loss, which becomes heat and could damage the device. Therefore, the three-way current limit, current shutdown, and overheat limit increase the certainty of protection.

■ Short-circuit protection function

The short-circuit protection function prevents overcurrent when a load connected to the output VOUT of the TCKE8xx series eFuse IC, or a power supply IC fails and a short-circuit occurs. The eFuse IC determines that a short-circuit occurs when the output current IOUT exceeds 1.6 times the output current limit set by the ILIM pin within a very short time. It immediately turns off the internal MOSFET to shut down VIN and VOUT and suppresses IOUT to almost zero. From the start of overcurrent due to short-circuit to the interruption, the time to shut down is 150 ns (typ.), which is very fast. The shorter the time to shut down, the less damage will be done to the load device. High-speed short-circuit protection characteristics is an important indicator of the performance of electronic fuses. The TCKE8xx series eFuse ICs deliver high-speed performance, due to Toshiba's advanced short-circuit protection technology.



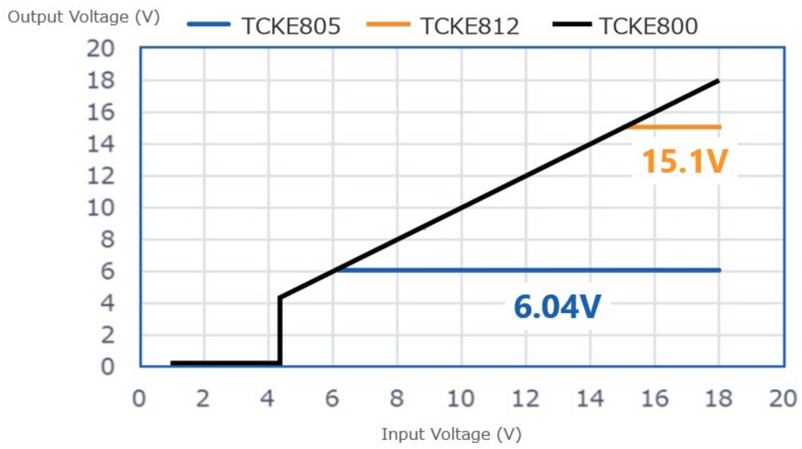




It seems to me that overcurrent protection and short-circuit protection are similar. So what are the differences?

Overcurrent protection operates when the output current exceeds the set limit value, and continues to allow current flow at that limited value. Short-circuit protection basically causes the maximum current of the input power supply to flow instantly when the output is short-circuited, so it detects it and immediately shuts it down to make the output current almost zero. This initial operation is the big difference.

■ Overvoltage clamp function

The overvoltage clamp is a function that keeps VOUT within the set limit value and prevents the overvoltage from being applied to the load device. The input voltage VIN of the TCKE8 series eFuse IC can be applied up to 18.0V. But some products are equipped with an overvoltage clamp circuit to protect the load device from input overvoltage when used on a 5V / 12V power rail (Not all products). Applicable products clamp the voltage applied to VIN at 6.04V / 15.1V (typ) and output. When the overvoltage clamp function is activated, the power consumption of the eFuse IC generates heat, so the thermal shutdown function works in the same way as overcurrent protection and short circuit protection.



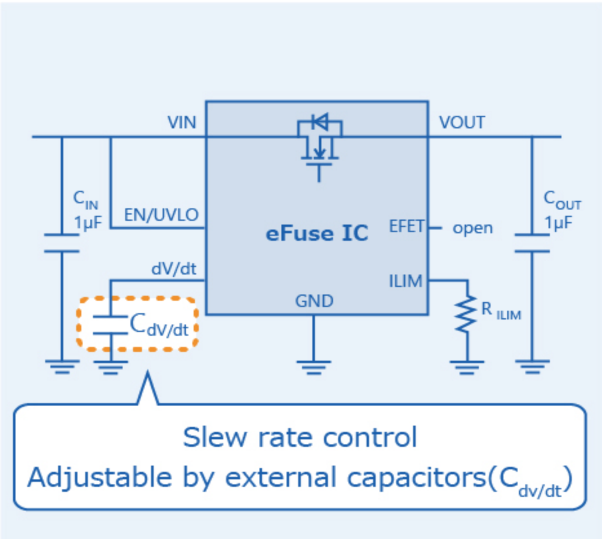

The VIN may be lower than the operating voltage of the eFuse IC, as opposed to the input overvoltage.
In that case, the eFuse IC and subsequent ICs may malfunction, so a low voltage malfunction prevention function (UVLO: Under Voltage Lockout) is also installed. Due to the UVLO function, the TCKE8xx series will not operate unless the VIN is 4.15 V (typ) or higher at startup and will stop operating if the VIN falls below 3.95 V (typ) after startup. The UVLO threshold can be adjusted by attaching an external resistor to the EN/UVLO pin.

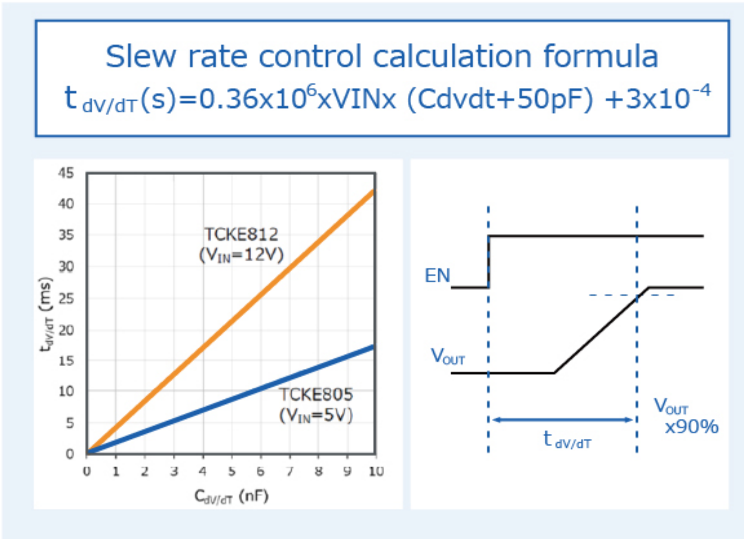
Is there protection not only on the output side but also against input issues?

There are many cases where the input power supply fluctuates greatly. For example, if the input voltage becomes excessive, almost the same voltage will be applied to the load device via the eFuse IC without any protection. If the load device is damaged and overcurrent flows, it is possible to limit or cut off this overcurrent, but it will already be too late. In that respect, it can be said that the overvoltage clamping function protects the eFuse IC itself and the load device.

■ Function to suppress inrush current (slew rate control function)

When the MOSFET inside the eFuse IC turns on and the input and output become conductive, the charging current immediately flows to the capacitor at the output. This is called an inrush current, and if it is too large, the overcurrent protection circuit may malfunction - making it impossible to start up or overshooting the output voltage. The function to suppress inrush current controls the rise (slew rate) of the output voltage so as to limit the inrush current to the capacitor, and thereby prevent these inconveniences. In case of the TCKE8xx series eFuse IC, placing an external capacitor at the dV/dT pin will provide the function of controlling the slew rate of the output voltage, so startup can be optimized according to the circuit requirements. The capacitance value of the external capacitor can be easily calculated from the formula described in the datasheet or the graph.



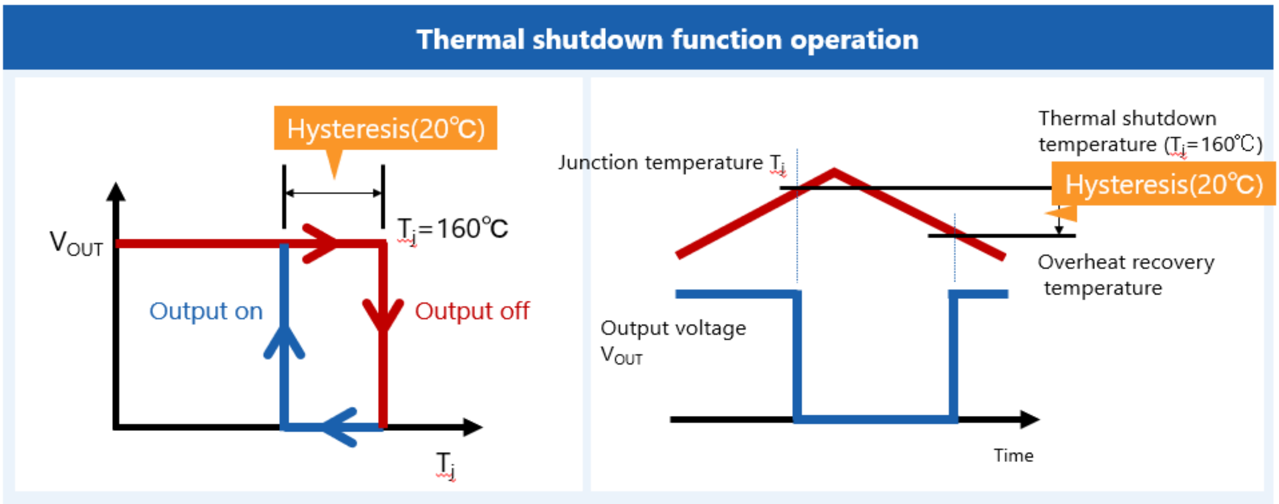

In the waveform at startup, the rising slew rate of VOUT is controlled, with the rise witnessed being gradual, so the charging current to the capacitor at the output also increases gradually, and it can be seen that the inrush current is sufficiently suppressed.

The power supply IC has a function called soft start for a similar purpose. Is that the same?

The purpose and control method are basically the same. By slowly raising the output voltage, the capacitor on the load side is charged little by little, so that a large current does not flow at once.

■ Thermal shutdown function

The thermal shutdown function turns off the built-in MOSFET when the junction temperature (Tj) of the eFuse IC exceeds the set value. This protects the eFuse IC by turning it off to block the output. Toshiba has the product that the interruption lowers the Tj and restores it when it falls below a threshold with hysteresis, and the other type that latches after shutting off. The figure 14 shows an example of the TCKE8xx series.




Why is there hysteresis in the threshold value at which thermal shutdown is activated?

Without hysteresis, there is a possibility of the operation going into an oscillating state which repeatedly shifts from on to off (and vice-versa) when the temperature is near the threshold value. This is not good for the eFuse IC and the load, so it serves as a way to prevent unstable behavior by making a difference between the on and off thresholds. This is used not only in temperature, but also in voltage and current comparison circuits.

By the way, you said that thermal shutdown is involved in each protection operation of overcurrent, short-circuit, and overvoltage. Why is that?

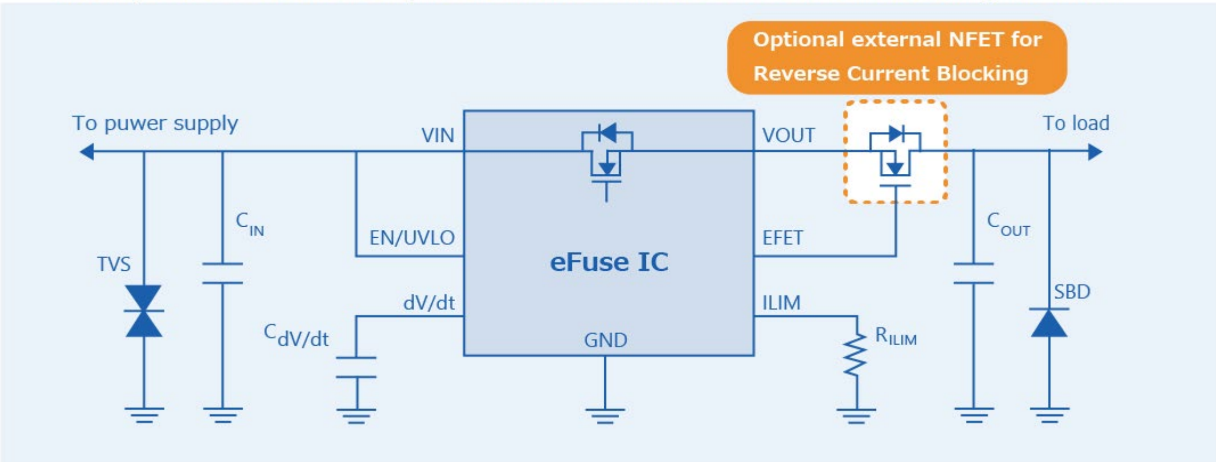
The reason why ICs are damaged by overcurrent or overvoltage situations is that the power loss becomes heat and causes burning or melting. For example, if the ambient temperature is high, the junction temperature Tj may be exceeded even if the current and voltage are within the rating. Also taking these things into consideration, combining current and voltage detection protection with temperature protection provides much more reliable overall protection.

■ Reverse current blocking function

The reverse current blocking function prevents flowing back the current from the output side to the input side through the parasitic (body) diode of the built-in MOSFET, when the voltage on the input side through the parasitic (body) diode of the built in MOSFET, when the voltage on the output side is higher than that on the input side during the operation of the eFuse IC has stopped (VIN power off, disable state, etc.).

This function is optional and requires one external MOSFET for the TCKE8xx series. EFET pins are provided to control the reverse current blocking MOSFET. So, all you have to do is add the MOSFET to the output line (as shown in the schematic). Please refer to the datasheet for recommended products and specifications for the reverse current blocking MOSFET.

Examples of eFuse IC Peripheral Circuits with Reverse current blocking Function




Why is this an optional function?

Depending on the application, eFuse IC such as the TCKE712BNL, which has a built-in MOSFET for reverse current blocking, may be useful. However, it is not necessary if there are no conditions for reverse current or if don't have to concern about reverse current. Another advantage is the on-resistance of VOUT is reduced, which reduces power losses, because VOUT does not go through the reverse current protection MOSFET.

The TCKE8xx series has an EFET pin for easy addition of reverse current blocking function by simply adding a MOSFET. Without this function, it would be necessary to change to another IC with a built-in reverse current blocking function or to prepare a separate MOSFET control circuit. So that is a useful option.

## What are the applications of the eFuse IC?

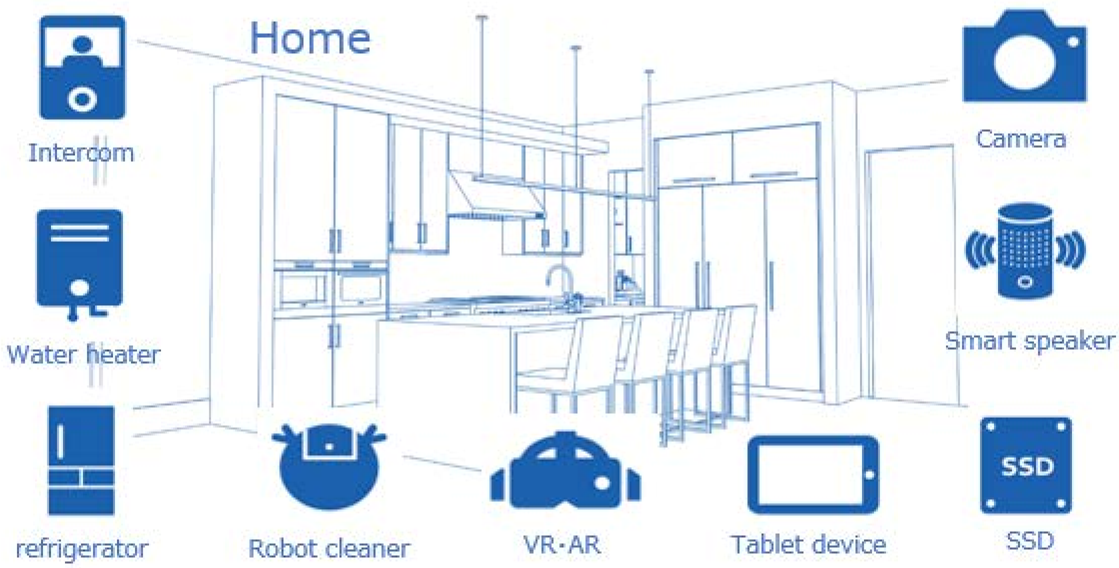
So eFuse ICs are very useful not only in terms of performance and functionality, but also in complying with safety standards?

Yes, that's right. For equipment requiring IEC62368-1 certification, the certified eFuse ICs are very convenient.

What kind of applications are they used for?

There are a wide variety of applications that will benefit from using eFuse ICs. For example, they can assure safety servers, notebook PCs, SSD / HDDs, printers, games consoles, VR and AR equipment, smart speakers and headsets. Simply, it can be used for virtually any electronic device that requires a power source, and safety considerations dictate that it should be used.

## Products that use eFuse ICs

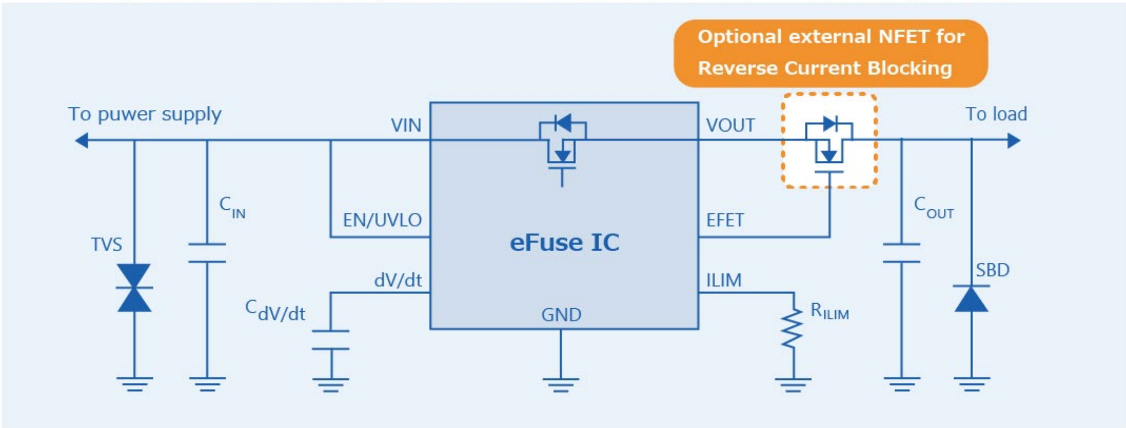



## Circuit example of eFuse IC

It really can be used in many applications. In the overview of the TCKE8xx series, there was a basic circuit example, but what is the actual circuit diagram?

Basically, the circuit is simple. Here are a few examples.

Examples of eFuse IC Peripheral Circuits with Reverse current blocking Function




It seems to be simpler than I expected, and easy to design with few external components. How can we receive all the necessary materials for the actual design?

For design, manufacturers provides not only data sheets but also design manuals and reference designs, which are examples of circuits whose operation has been verified. This kind of information and tools can be used to reduce development time.

Toshiba has prepared the following information and materials for design support of the TCKE8xx eFuse IC series.

Thank you!

We provide the following information and materials to support the design of eFuse IC series.

→ Reference design

→ eFuse IC product page

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