Comparison of eFuse IC and Conventional Fuse Characteristics Application note

Overview

eFuse ICs are Protection ICs, also known as semiconductor fuses or electronic fuses. As a conventional type fuse, a fuse with a glass tube is generally used, but as a protective element on an electronic circuit board, a blown type one-shot type chip fuse, a reusable resettable fuse, etc. are used. eFuse ICs offer a variety of advantages over conventional fuses. This document compares our eFuse ICs with conventional fuses in terms of their protective properties and explains the differences in their properties.

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1. Introduction

Glass tube fuses and blade fuses are used as safety parts to prevent overcurrent to electronic equipment. Recent miniature electronic devices also use repeatedly usable chip-type fuses (surface mount resettable fuses, hereafter referred to as resettable fuses).

All of them are protection devices using Joule heat generated by overcurrent, but they pose the challenge of low accuracy when interrupting current and time-consuming shut-off.

In addition, glass tube fuses that blow metal or chip fuses that cannot be reused (hereafter, one-shot chip fuses) will be damaged once circuit protection is activated, so there is a problem that fuses must be replaced in order to restart operation.

Semiconductor fuses (also known as eFuse ICs or electronic fuses, hereafter eFuse ICs) are drawing attention as a new type of protection fuse that meets the above-mentioned challenges.

The eFuse IC provides high-speed operation and high-precision overcurrent protection that is unique to semiconductors. It can also be used repeatedly, and it is easy to recover after shutdown.

This document introduces the results of comparing the characteristics of two types of chip fuses and our eFuse ICs.

2. Basic specifications of each fuse

Characteristics of various fuses are shown in Table 1.

eFuse ICs were compared with 3 types of fuse : a resettable fuse that can be used repeatedly, and a chip fuse (hereafter, a one-shot type chip fuse) that cannot be reused once it has been activated and glass tube fuse.

Table 1 Comparison table of various fuses1

	Glass tube fuse	One-shot type chip fuse	Resettable fuse	Electronic fuse or eFuse IC
Repeatability	-	-	✓	✓✓✓
Overcurrent protection Speed and accuracy	-	-	-	✓✓✓
Other protection functions	-	-	-	✓✓✓
Effect of ambient temperature	-	-	-	✓✓✓
Single unit mounting area	-	✓✓	-	✓
Total mounting area including protection circuit	-	-	-	✓✓✓
Cost of individual parts	✓	✓✓	-	✓
Total cost including function and maintenance	-	-	-	✓✓✓

3. Product specifications for evaluation

The products for evaluation are shown in Table 2.Table 2 Main Characteristics of Various Fuses (Values listed in data sheets)2

Three types of fuses were compared: an eFuse IC, a resettable fuse that can be used repeatedly, and a one-shot chip fuse that cannot be reused once it has been activated. The rated current of the products to be compared is about 3A.

Table 2 Main Characteristics of Various Fuses (Values listed in data sheets)2

	eFuse IC (TCKE812NL)	Resettable Fuse	One-shot type Chip fuse
Manufacturer	TOSHIBA	Company A	Company B
Size [mm]	3.0 x 3.0 x t0.7	7.3 x 7.7 x t1.1	1.0 x 0.5 x t0.5
Rated current	5.0 A	3.1 A (Hold Current)	3.0 A
Output limit current	3 A (R_{ILIM} = 35.7 kΩ)	—	—
Protection operation time ※1 (at output current of 5 A)	150 ns ※2	> 13 s	> 3 s
On-resistance	28 mΩ	13 – 36 mΩ	21 mΩ
Overvoltage protection function	Y	None	None

※1 A protection operation time is the time until the path is cut off when an overcurrent enters the device.

※2 In the case of eFuse IC, it corresponds to Fast-trip time. Fast Trip is an operation that quickly cuts off the current path when a current of ILIM x 1.6 times or more flows in the output current (IOUT) as shown in Fig. 1.

Fig.1 eFuse IC Timing Chart1

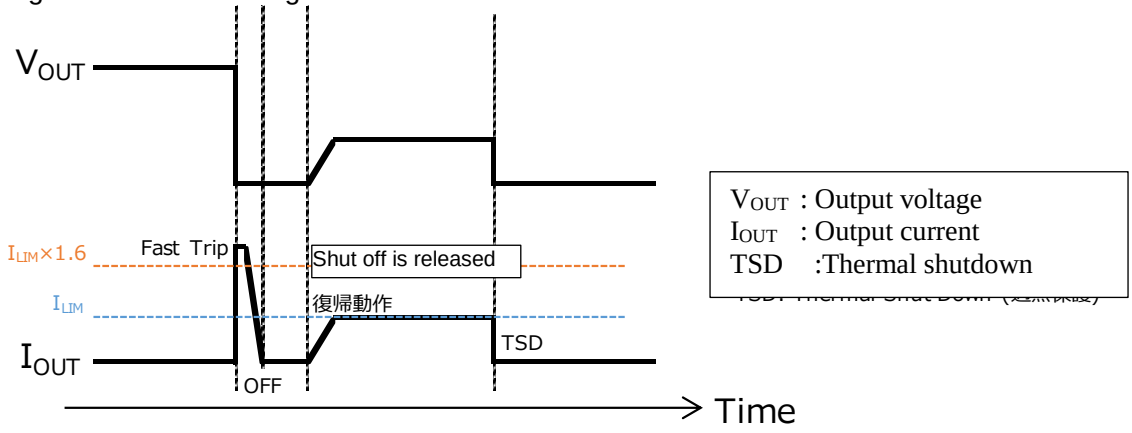

Fig.1 eFuse IC Timing Chart1

The evaluation boards and circuit diagrams used for the evaluation are shown in Fig 2, Fig 3, and Fig 4.Fig.2 eFuse IC Evaluation Board and Schematic2Fig.3 Evaluation Board for Resettable Fuse3

Fig.4 Evaluation Board for One-Shot Chip Fuse4

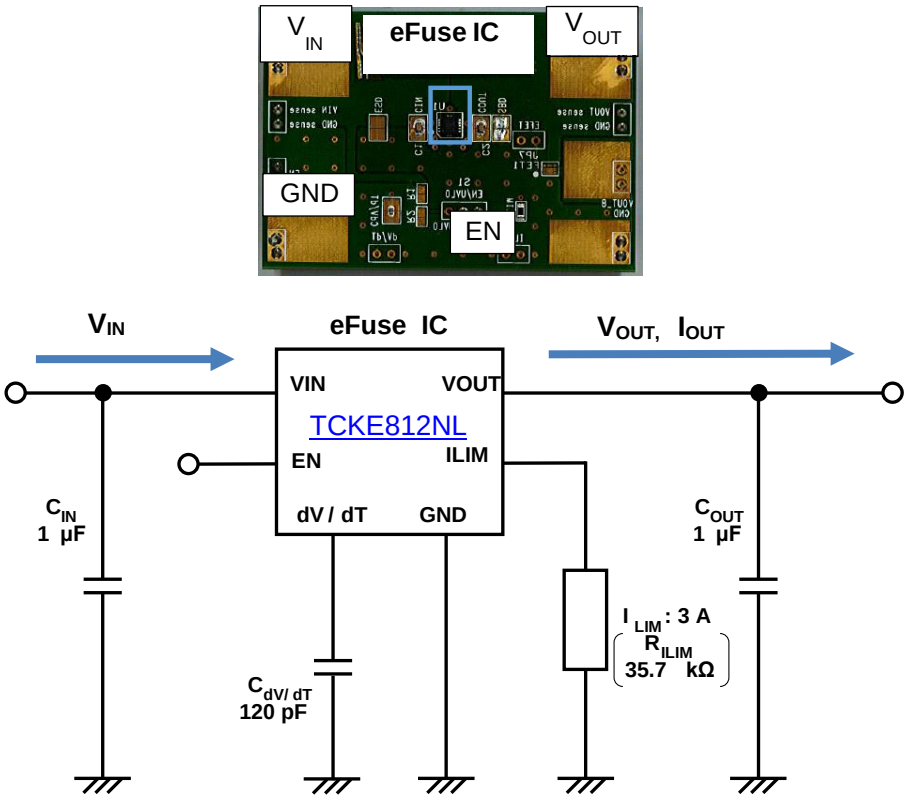

Fig.2 eFuse IC Evaluation Board and Schematic2

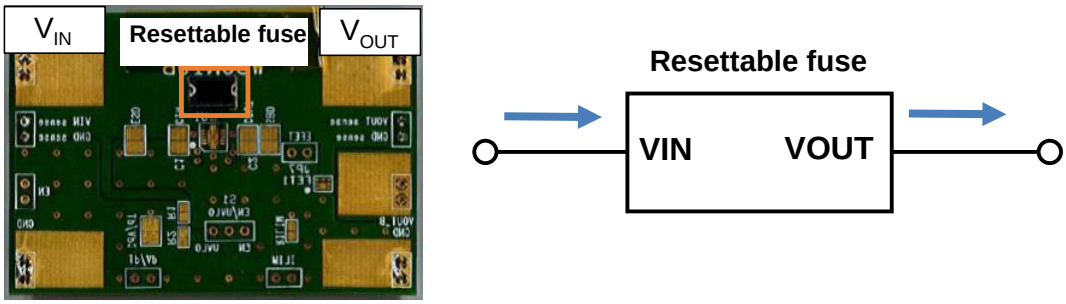

Fig.3 Evaluation Board for Resettable Fuse3

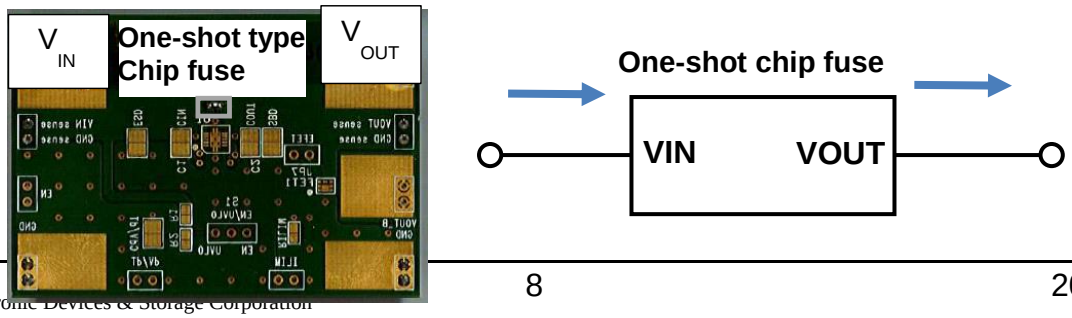

Fig.4 Evaluation Board for One-Shot Chip Fuse4

4. Comparison of Overcurrent Protection Characteristics

Overcurrent protection (OCP) is a function that stops output when the output current becomes larger than expected due to short-circuit of the output-side circuit, etc. Deterioration of the characteristics of the subsequent circuit, operation failure, breakage, etc. caused by excessive current flow can be prevented.

The overcurrent protection is compared for the period from when a current exceeding the specified current (5A and 10A) flows into the fuse to when it is shut off.

4.1 Evaluation method

The evaluation circuit for eFuse ICs is shown in Figure 5, and the evaluation circuit for resettable fuse and one-shot chip fuses is shown in Figure 6.Fig.5 eFuse IC Overcurrent Protection Estimation Schematic5Fig.6 Overcurrent Protection Evaluation Circuit Diagram for Resettable Fuses and One-Shot Chip Fuses6

The overcurrent is set by the load resistance R_{LOAD} and is evaluated for the two types of 5A (R_{LOAD}=2.4Ω) and 10A (R_{LOAD}=1.2Ω). The evaluation procedure is as follows.

- The input side of the fuse shall be a state in which DC voltage is applied by connecting a power supply.
- Turn the switch (SW) from open (OFF) to connect (ON). Thus, a sudden current (overcurrent) flows through R_{LOAD}.
- Measure the time from when the switch (SW) is connected (ON) until the fuse is shut off (protective operation).

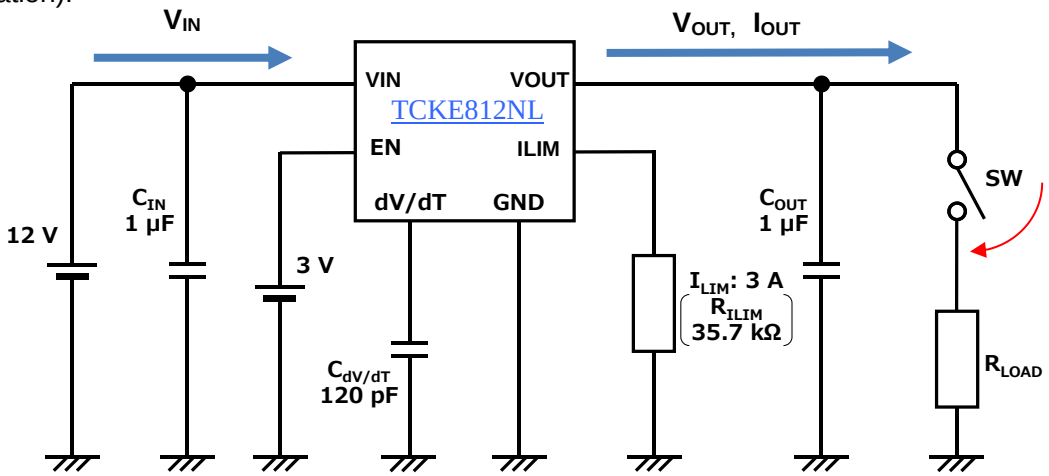

Fig.5 eFuse IC Overcurrent Protection Estimation Schematic5

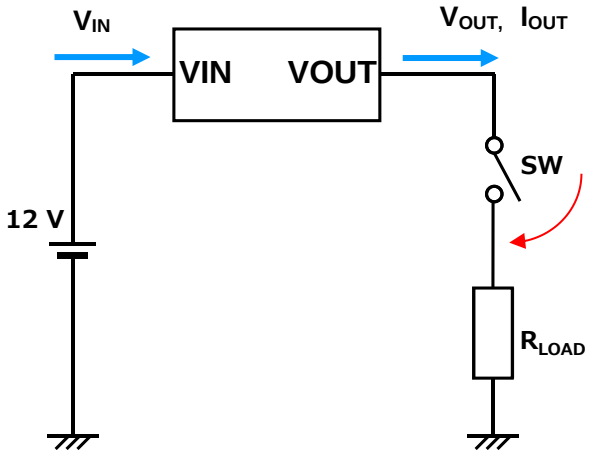

Fig.6 Overcurrent Protection Evaluation Circuit Diagram for Resettable Fuses and One-Shot Chip Fuses6

4.2 Evaluation-result I_{OUT} = 5 A (R_{LOAD} = 2.4 Ω)

Figure 7 shows the operation of various fuses at an overcurrent of 5 A.Fig.7 Evaluation result of overcurrent 5 A7

Although eFuse IC shut off the current path instantaneously, the resettable fuse and the one-shot type chip fuse did not shut off the current path even if 167 % of the overcurrent against the rating continued to flow for 8 s, and the protection function did not operate within the times shown in the figure.

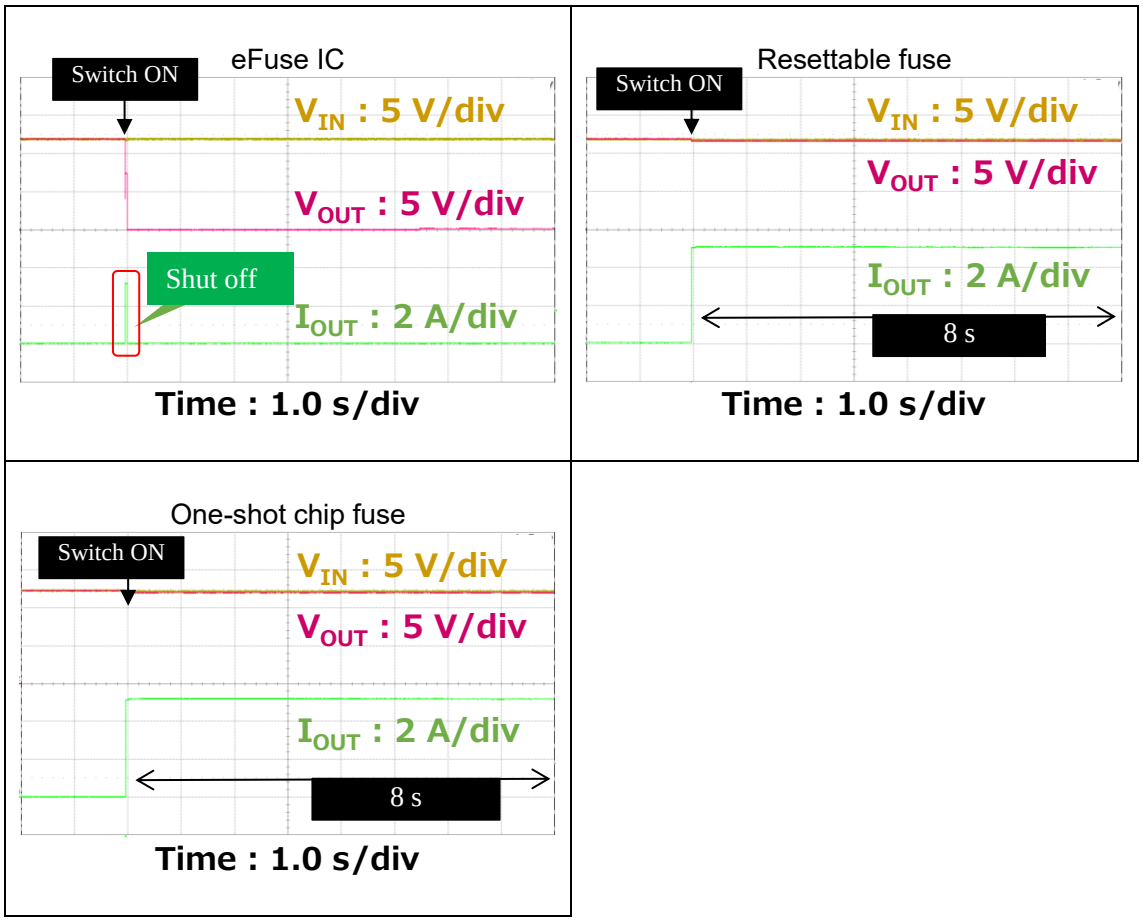

Fig.7 Evaluation result of overcurrent 5 A7

4.3 Evaluation-result I_{OUT} = 10 A (R_{LOAD} = 1.2 Ω)

Figure 8 shows the operation of various fuses when the overcurrent is set to 10 A.Fig.8 Evaluated overcurrent of 10 A (Time: 1.0 s/div) 8

eFuse IC and the one-shot chip fuse were able to shut off the current path instantaneously just as when the overcurrent was 5 A.

On the other hand, the resettable fuse took 2.6 s to cut off the current path.

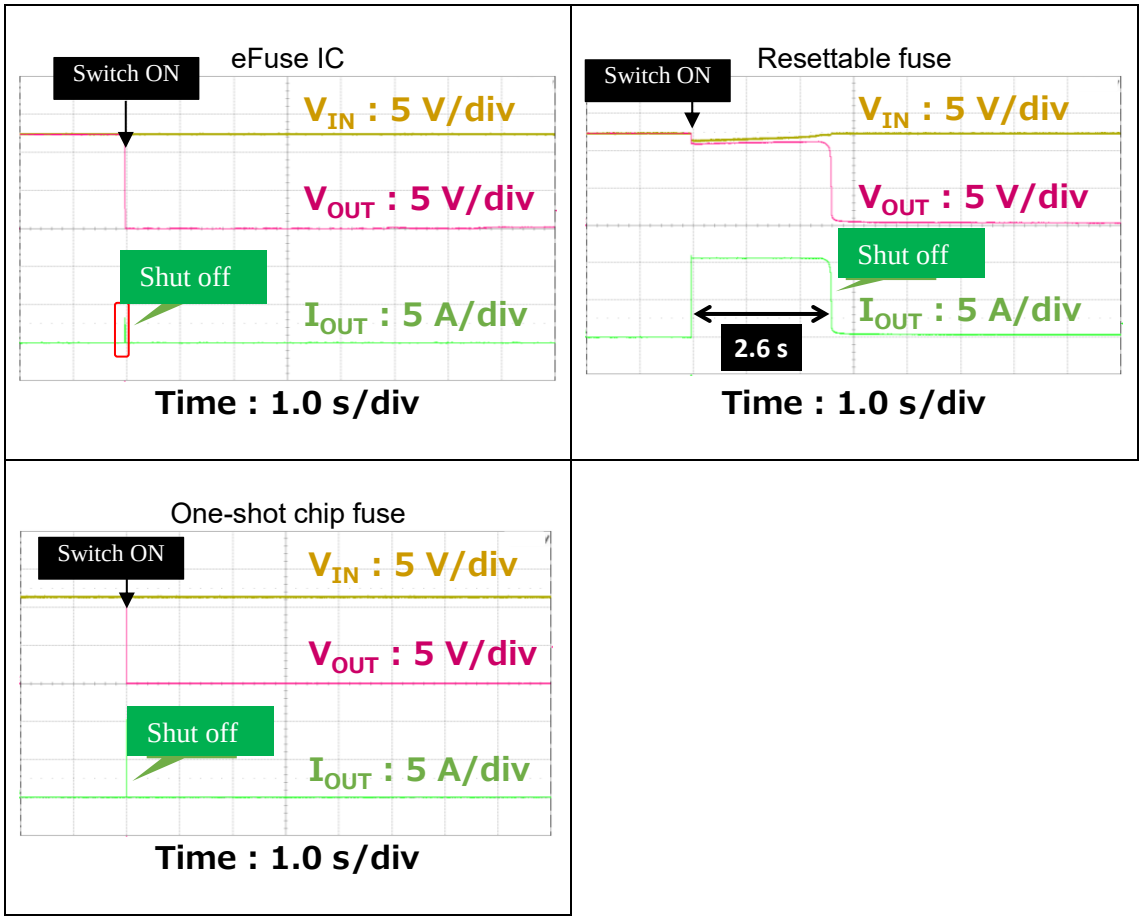

Fig.8 Evaluated overcurrent of 10 A (Time: 1.0 s/div) 8

eFuse IC and one-shot chip fuse are shown in Fig. 8 with a very short cut-off duration and more detailed comparisons with a time-base of 1.0 ms/div are shown in Fig. 9.Fig.9 Evaluated overcurrent of 10 A (Time: 1.0 ms/div)9

Consequently, eFuse IC interrupted the current path instantaneously (about 2μs: within the green frame in Fig. 9-left (1)), whereas the one-shot type chip fuse interrupted the path after 3.7 ms.

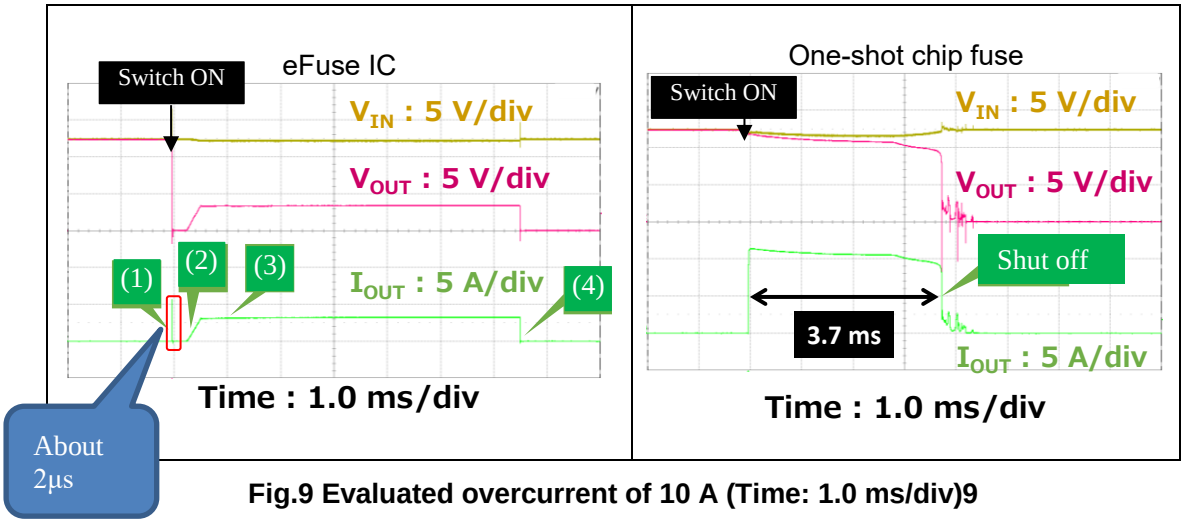

Fig.9 Evaluated overcurrent of 10 A (Time: 1.0 ms/div)9

In evaluating 10A setting this time, we have confirmed that the current path was interrupted by the conventional fuse. However, the time until interruption fluctuates depending on the ambient temperature as well as the current. Even with 5A setting, depending on the ambient temperature, it may be shut off in a short time.

On the other hand, for eFuse IC, the current path can be shut off as soon as the preset current value is exceeded, regardless of the ambient temperature, etc.

efuse IC is recommended if you wish to shut off the current path accurately and immediately to protect the subsequent circuitry.

This section explains the behavior of eFuse IC after the overcurrent protection function is activated (Fig. 9, left side).

- When an overcurrent occurs, the eFuse IC cuts off the current after detecting the overcurrent. (in the red frame in Fig. 9 (1)).Fig.9 Evaluated overcurrent of 10 A (Time: 1.0 ms/div)9
- Thereafter, after several hundred μs, the interruption of the current path (conduction) is released (the portion (2) in Fig. 9).Fig.9 Evaluated overcurrent of 10 A (Time: 1.0 ms/div)9
- At this time, if the overcurrent has not been eliminated, I_{OUT} is limited to 3 A (I_{LIM}) by the overcurrent limiting function (as shown in (3) in Fig. 9).Fig.9 Evaluated overcurrent of 10 A (Time: 1.0 ms/div)9
- If eFuse IC continues to flow 3 A, the chip temperature rises due to heat dissipation, resulting in overheat protection (TSD).
  The current path is interrupted again (in Fig. 9 (4)).Fig.9 Evaluated overcurrent of 10 A (Time: 1.0 ms/div)9

As described above, eFuse IC recovers after confirming that the input current has returned to the normal range after an overcurrent has occurred.

Please refer to the linked document (Application Note) for detailed operation of the product. → Click Here

5. Comparison of Short Circuit Protection Characteristics

The short-circuit protection function prevents excessive current from flowing when the power line or load is short-circuited due to an error.

This short-circuit protection characteristic comparison is performed for the period from the short circuit on the output side of the fuse to the interruption of the current, and for the maximum value of the instantaneous current.

5.1 Evaluation method

Figure 10 shows eFuse ICs evaluation circuit and Figure 11 shows the evaluation circuit for resettable fuses and one-shot chip fuses.Fig.10 Short Circuit Diagram of eFuse ICFig.11 Short-Circuit Protection Evaluation Circuit Diagram for Resettable Fuses and One-Shot Chip Fuses10

The evaluation procedure is as follows.

・DC voltage is applied by connecting a DC power supply to the input side of the fuse.

・Connect the output-side V_{OUT} of the fuse and GND with a switch (SW), and turn the switch OFF (open).

・Turn the switch (SW) from OFF (open) to ON (short) to short-circuit the output side of the fuse.

・Measure the time from when the switch (SW) turns ON (short) until the fuse cuts off the path (protection action) and the current value flowing through the fuse output.

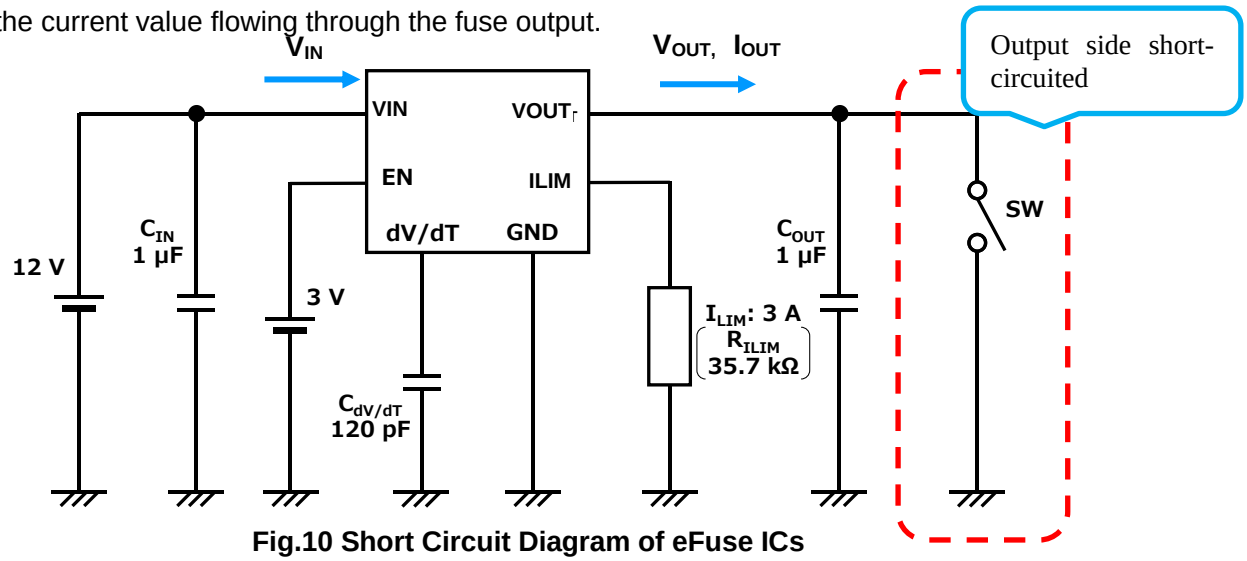

Fig.10 Short Circuit Diagram of eFuse ICs

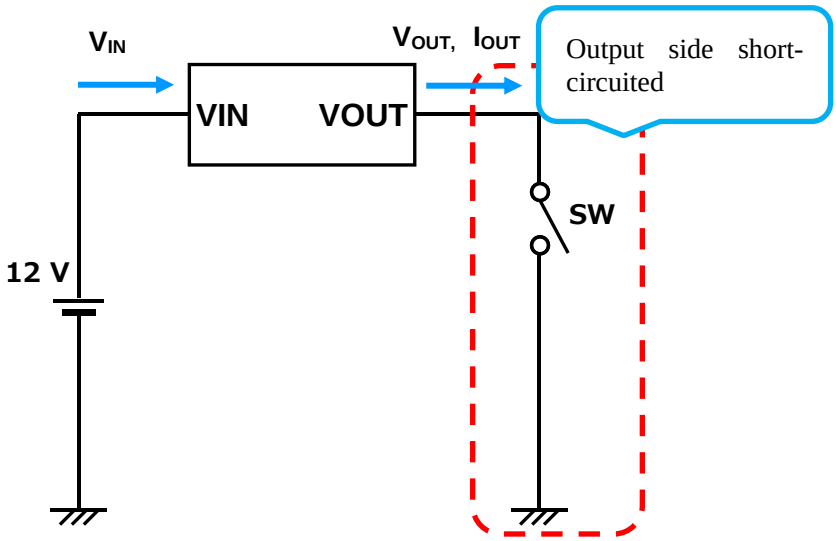

Fig.11 Short-Circuit Protection Evaluation Circuit Diagram for Resettable Fuses and One-Shot Chip Fuses10

5.2 Evaluation Results

The evaluation results for various fuses are shown in Figure 12. In Figure 12, the resettable fuse failed to observe the time until the current path was shut off, so the evaluation result of widening the time base is shown in Figure 13.Fig.12 Evaluation results of short-circuit current of various fuses

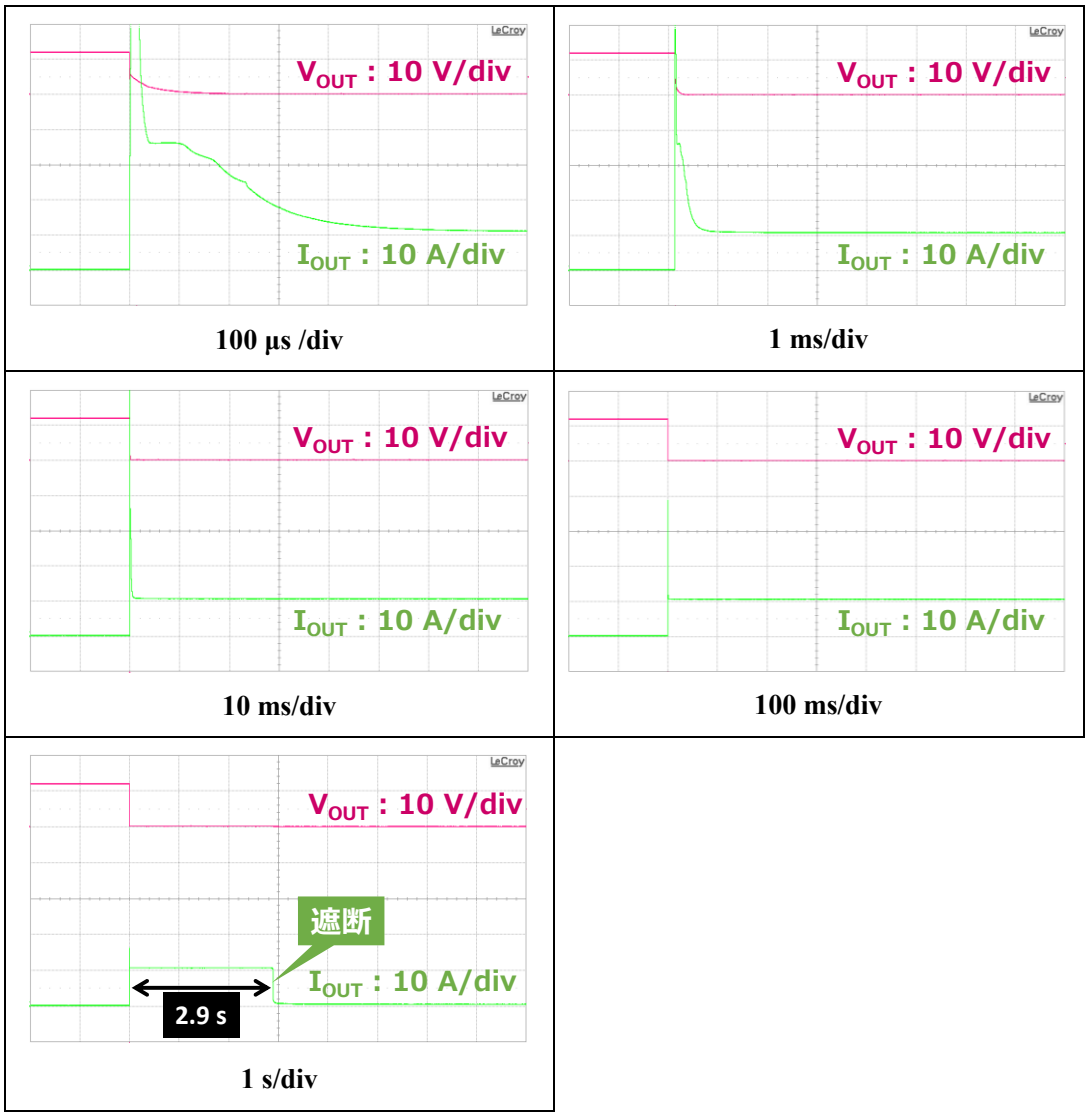

Fig.13 Evaluation result of widening the time axis of the Resettable fuse

11Fig.12 Evaluation results of short-circuit current of various fuses

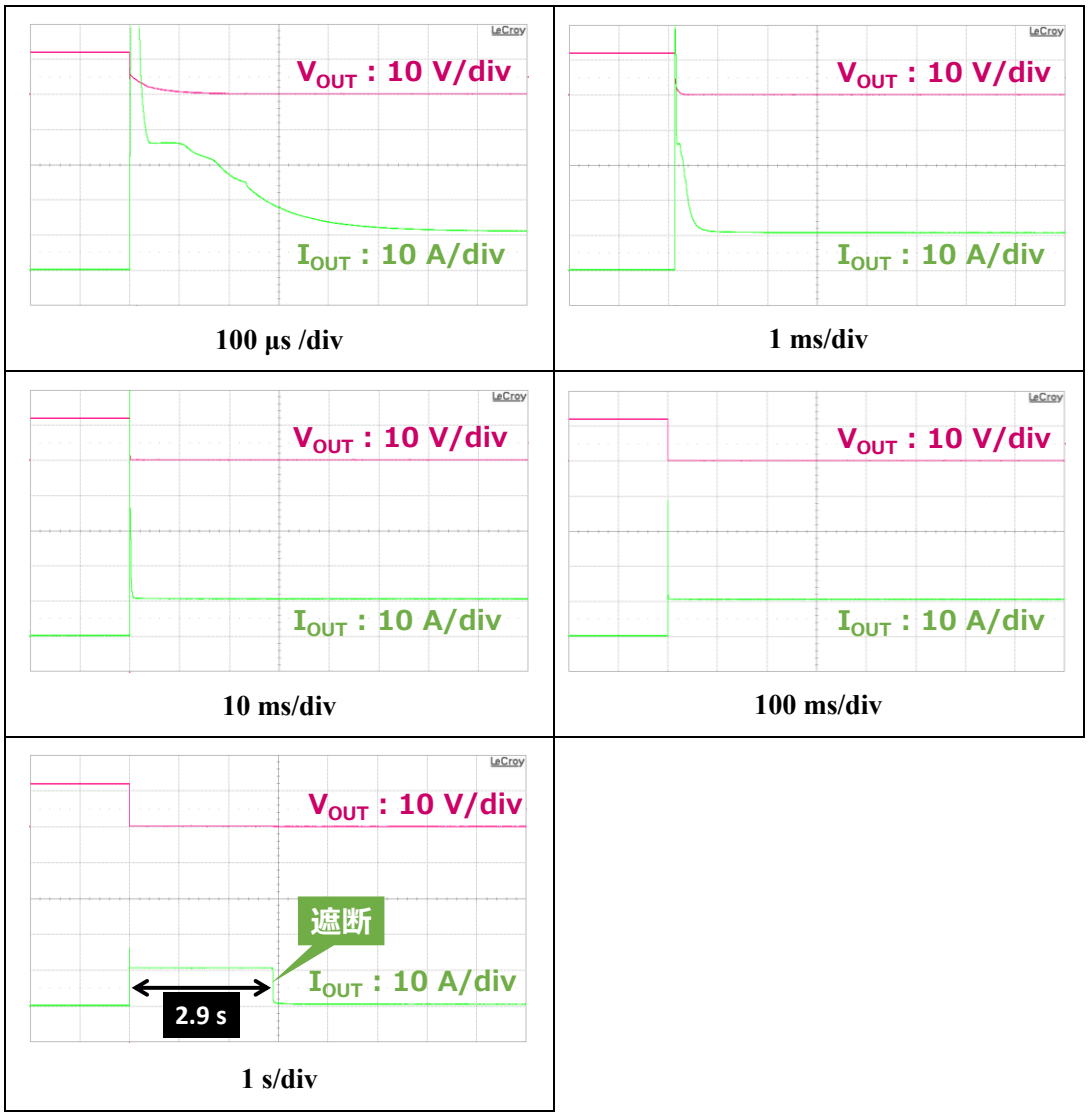

Fig.13 Evaluation result of widening the time axis of the Resettable fuse

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Table 3 Results of Short Circuit Protection Evaluation for Various Fuses3

Compared with conventional fuses, eFuse IC has a shorter path shut-off time when shorted, and has a lower maximum I_{OUT} and superior protection performance.

A large current of 70 A or more flows into the resettable fuse when it is short-circuited, but I_{OUT} is suppressed to about 10 A after about 500 µs . This is considered to be the effect of the power supply used for the evaluation, rather than the current limiting function of the resettable fuse (because the current rating of the power supply is 10 A and it is impossible to carry a current above the rating). Interrupted after 2.9s after short-circuit. The one-shot type chip fuse also had a large current that exceeded 70A at the time of short circuit.

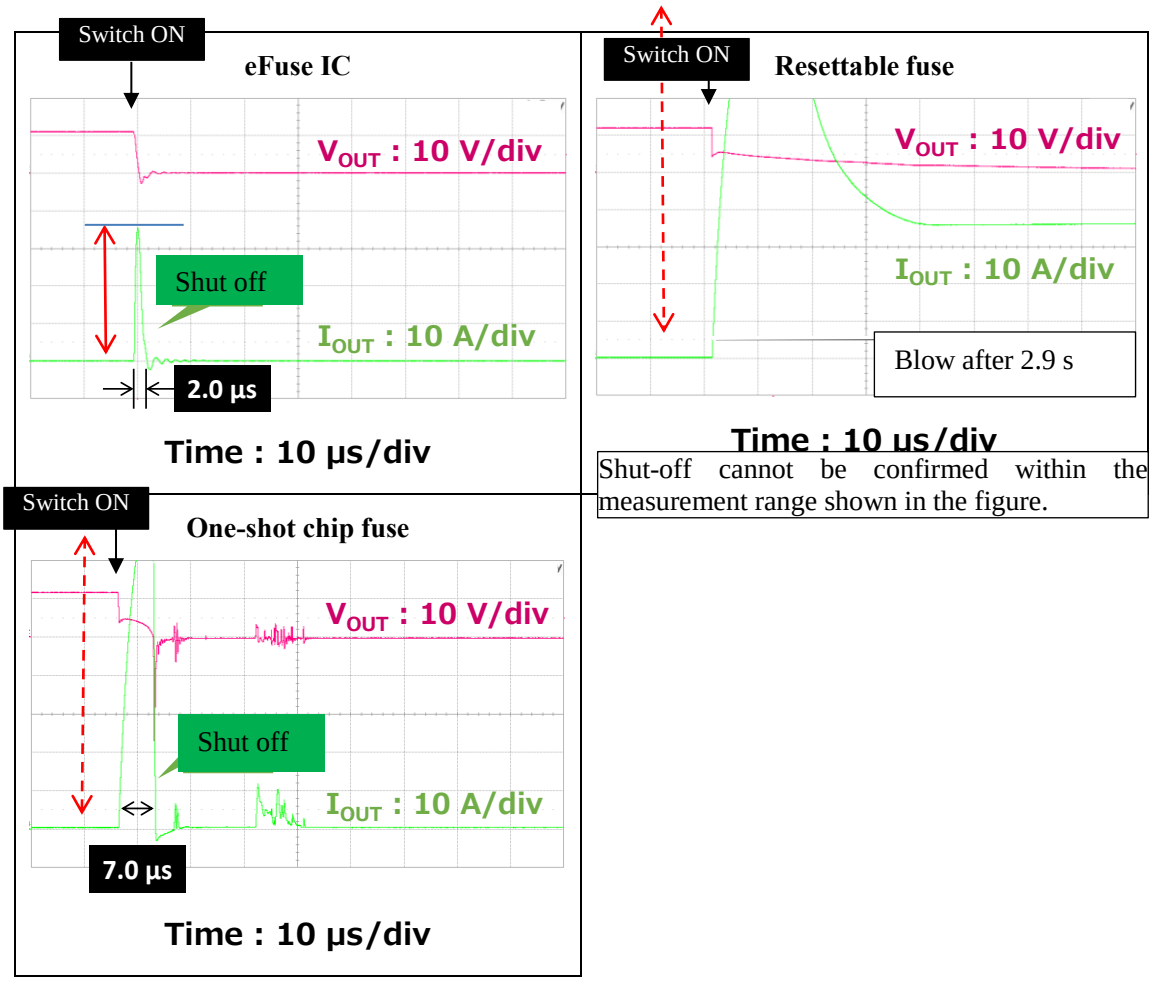

Fig.12 Evaluation results of short-circuit current of various fuses

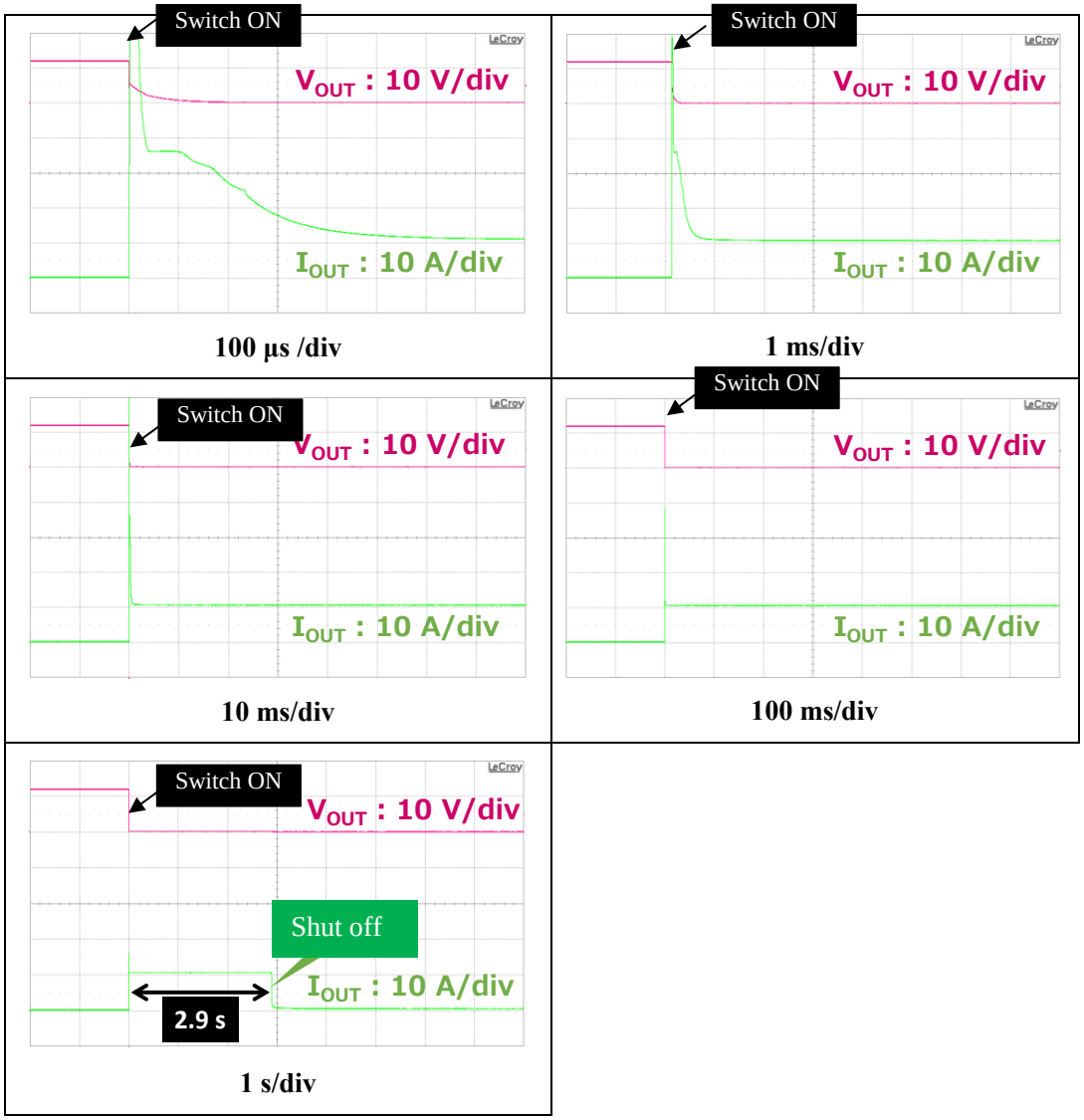

Fig.13 Evaluation result of widening the time axis of the Resettable fuse

Table 3 Results of Short Circuit Protection Evaluation for Various Fuses3

	eFuse IC	Resettable fuse	One-shot chip fuse
Protection function operation time	2.0 µs	2.9 s	7.0 µs
Output maximum current	35 A	> 70 A	> 70 A

From the above, we were able to confirm that both eFuse IC and conventional fuses cut off the current path. eFuse IC is ideal when you want to suppress the maximum current value on the output side as low as possible in a shorter time when a short circuit occurs.

5.3 [Supplement] Enhancements to IC protection (Addition of Schottky Barrier Diode (CUHS20S30))

After eFuse IC's short-circuit protection function is activated, a negative spike voltage may occur in the VOUT.

This is because when a large current flows into eFuse IC, if the path is cut off and V_{OUT} decreases rapidly, a negative spike-voltage is generated at the output-side due to the back electromotive force of the inductance component of the wiring.

Negative spike voltage generation may lead to malfunction of the subsequent IC or product destruction.

To suppress this negative spike-voltage, a Schottky barrier diode (SBD:CUHS20S30) was connected to the output to evaluate the short-circuit characteristics. The evaluation circuit is shown in Figure 14.Fig.14 Short-circuit protection evaluation circuit of eFuse IC with SBD connected to the output side12

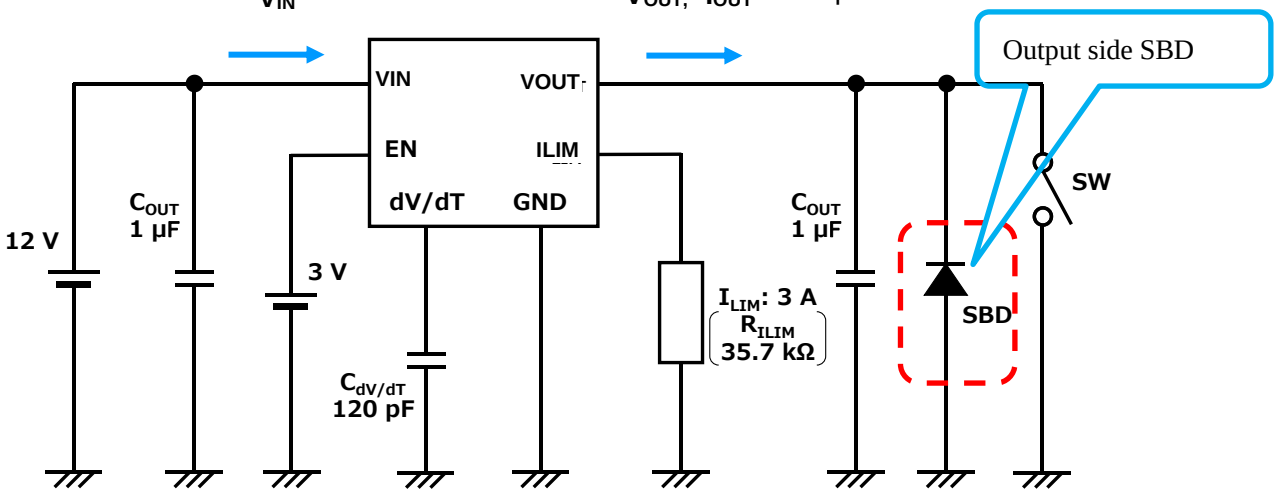

Fig.14 Short-circuit protection evaluation circuit of eFuse IC with SBD connected to the output side12

<Evaluation Results>

Figure 15 shows the results of the comparison evaluation with and without the output-side SBD.Fig.15 Evaluated short-circuit current of eFuse IC (with/without SBD)13

Without the SBD (above figure in Figure 15: When the SBD is not connected to the fuse output side), V_{OUT} has a negative spike voltage of-2.7 V.

On the other hand, when the SBD is present (Fig. 15 below: When connected to the fuse output side), the negative spike voltage of V_{OUT} is-1.1 V, which indicates that it is suppressed.

However, the time from the short-circuit state to shutting off the current path was 2.0 μs without SBD, but it was around 4.0 μs with SBD.

This is considered to be the effect of the SBD becoming a capacitance component.

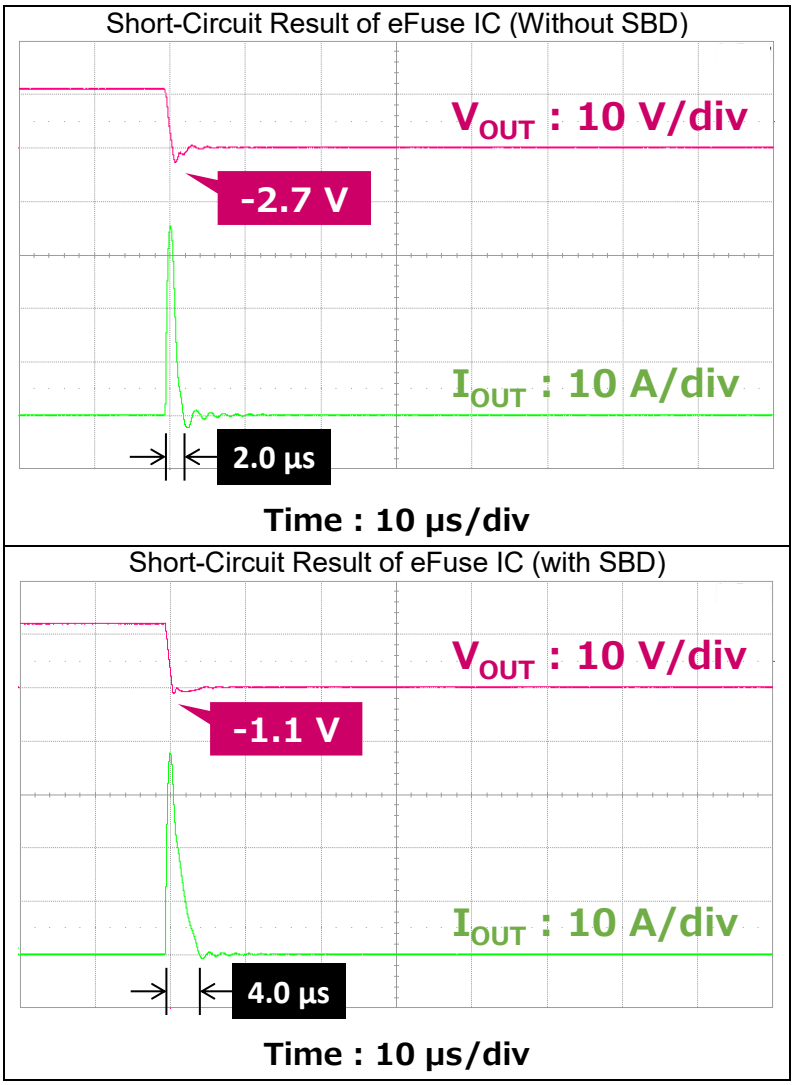

Fig.15 Evaluated short-circuit current of eFuse IC (with/without SBD)13

Introduction to Schottky Barrier Diodes (SBDs) → Click Here

Schottky Barrier Diode (SBD) CUHS20S30 product info → Click Here

6.Summary

We evaluated the overcurrent protection and short-circuit protection characteristics of the conventional fuse (rated current is 3 A) and the eFuse IC (TCKE812NL) whose I_{LIM} is set to 3 A.

The results obtained from this evaluation are shown in Table 5.Table 4 Summary of Evaluation Results4

eFuse IC can shut off the current path instantaneously at all times when overcurrent is 5 A or 10 A or short circuit, and it has been confirmed that it is safer than conventional fuses as a protection device against overcurrent.

Conventional fuses are also considered to have sufficient protection characteristics if the breaking time is within the allowable range.

Table 4 Summary of Evaluation Results4

	eFuse IC	Resettable fuse	One-shot chip fuse
During overcurrent, Fuse operation	5 A : shut-off 10 A : shut-off	5 A : Continuity 10 A : shut-off	5 A : Continuity 10 A : shut-off
During a short circuit Protective operation time	2.0 μs	2.9 s	7.0 μs
During a short circuit Output maximum current	35 A	> 70 A	> 70 A

Now that product safety is strongly required, eFuse ICs are considered to be a promising candidate for fuse selection, considering a variety of protection functions, total mounting area including those functions, and high-speed protection properties.

In this document, we compared and evaluated the protection characteristics of eFuse ICs and conventional fuses. The eFuse ICs is a very effective product for protecting the subsequent circuit (electronic device) when connecting wiring while the power is on, such as when inserting or removing hot wires.

When using eFuse ICs, please refer to this application note and consider our lineup.

Parametric search of eFuse ICs is here → Click Here

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