TOSHIBA

TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

TCKE9 Series

23V, 4A eFuse IC with Adjustable Overcurrent Protection and High Speed Overvoltage clump.

The TCKE9 series is 23 V high input voltage Single Input-Single Output eFuse ICs. It can be used as a reusable fuse, and includes protection features like adjustable over current limit by an external resistor, short circuit protection, over voltage clamp, adjustable slew rete control by an external capacitance, adjustable under voltage protection by external resistor and thermal shutdown.

Switch ON resistance is only 34 mΩ (Typ.) and high output current is up to 4.0 A characteristics makes this series is suitable for protecting the power supply circuit of USB VBUS line, storage power supply circuit and battery charging application, etc.

This series is available in 0.5mm pitch small package WSON8 (2.0 mm (Typ.) x 2.0 mm (Typ.), t: 0.8 mm (MAX)). Thus, this series is ideal for various applications such as portable electronics that require high-density soldering.
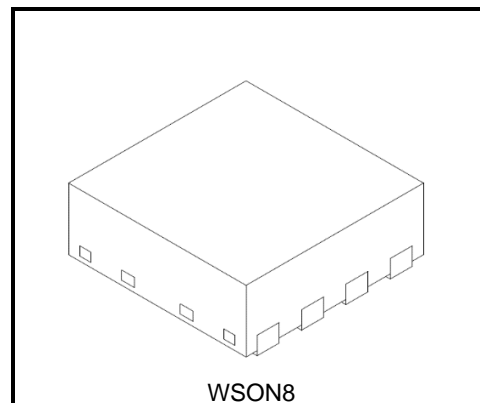
WSON8

Weight: 7.99 mg (typ.)

Feature

- High input voltage: V_{IN} = 25.0 V (Max)
- Low ON resistance R_{ON}: 34 mΩ (Typ.)
- Adjustable overcurrent limit: 0.5 A to 4.0 A
- Fixed over voltage clamp
    - TCKE903: V_{OVC} = 3.87 V (Typ.)
    - TCKE905: V_{OVC} = 5.7 V (Typ.)
    - TCKE912: V_{OVC} = 13.7 V (Typ.)
    - TCKE920: V_{OVC} = 22.2 V (Typ.)
- Adjustable slew rate control by external capacitance for inrush current reduction
- Adjustable under voltage lockout by external resistor
- Thermal shutdown
- Quick output discharge: TCKE903QNA, TCKE905QNA
- Small package : WSON8 (2.0 mm (Typ.) x 2.0 mm (Typ.), t: 0.8 mm (Max)).
- IEC62368-1 (G9: Integrated circuit (IC) current limiters) Certified (Under planning)

Notice

This series is sensitive to electrostatic discharge.

Please ensure equipment and tools are adequately earthed when handling.

Start of commercial production
2024-03

2025-05-20
Rev.9.0

1. Absolute Maximum Ratings (Note) (Ta = 25 °C)

Characteristics	Symbol	Rating		Unit
Input voltage	V_{IN}	-0.3 to 25.0		V
ILIM voltage	V_{ILIM}	-0.3 to 6.0		V
dV/dT voltage	$V_{dV/dT}$	-0.3 to 6.0		V
Control voltage	$V_{EN/UVLO}$	-0.3 to 25.0		V
Output voltage	V_{OUT}	-0.3 to V_{IN} + 0.3 or 23 which is smaller		V
Output voltage	V_{OUT_PLS}	< 1μs Pulse	-1.2 (Min)	V
FLAG voltage	V_{FLAG}	-0.3 to 6.0		V
QOD voltage	V_{QOD}	-0.3 to 6.0		V
FLAG sink current	I_{FLAG}	0 to 10		mA
Power dissipation	P_D	2.0 (Note 1)		W
Junction temperature	T_j	150		°C
Storage temperature	T_{stg}	-55 to 150		°C

Note: Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings. Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/"Derating Concept and Methods") and individual reliability data (i.e. reliability test report and estimated failure rate, etc).
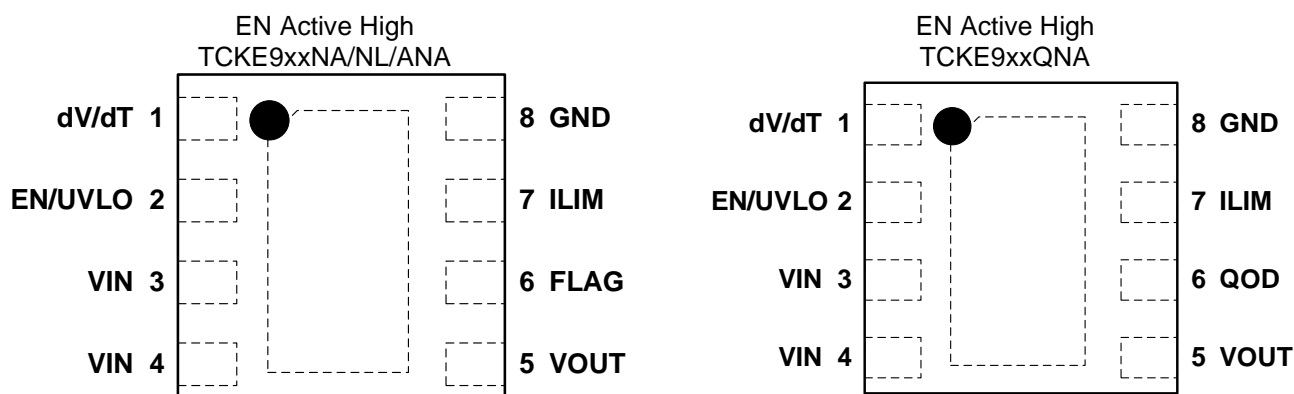
Note 1: Rating at mounting on a board: FR4 board. (76.2 mm × 114.3 mm × 1.6 mm, 4 layer)

2. Operating Ranges

Characteristics	Symbol	Ranges		Unit
Input voltage	V_{IN}	TCKE9xxNA/NL/ANA	2.7 to 23.0	V
		TCKE9xxQNA	3.0 to 23.0	V
Output current	I_{OUT}	DC	0 to 4.0	A
ILIM External resistance	R_{ILIM}	487 to 5000		Ω
Control voltage	$V_{EN/UVLO}$	0 to 23		V
FLAG voltage	V_{FLAG}	0 to 6		V
QOD votage	V_{QOD}	0 to 6		V
FLAG sink current	I_{FLAG}	0 to 10		mA
Operation junction temperature	T_{j_opr}	-40 to 125		°C
External capacitance	$C_{dV/dT}$	3300 (Min)		pF

3. Pin Assignment (Top view)

WSON8

EN Active High
TCKE9xxNA/NL/ANA

dV/dT	1		8	GND
EN/UVLO	2		7	ILIM
VIN	3		6	FLAG
VIN	4		5	VOUT

EN Active High
TCKE9xxQNA

dV/dT	1		8	GND
EN/UVLO	2		7	ILIM
VIN	3		6	QOD
VIN	4		5	VOUT

4. Top Marking (Top view)

Example: TCKE903NA

INDEX

903NA
XXXX

Lot code   Product code
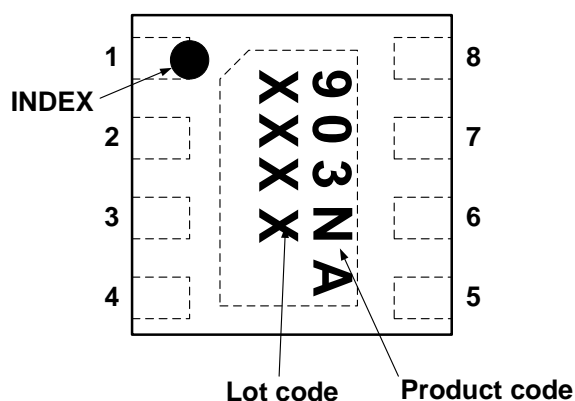
4.1. Product list

Part number	Over voltage Clamp	$V_{EN/UVLO}$ function	Fault Response	Top Marking	Quick output discharge	Package
TCKE903NA	3.87 V (Typ.)	Active High	Auto-retry	903NA	None	WSON8
TCKE903NL	3.87 V (Typ.)	Active High	Latched	903NL	None	
TCKE905ANA	5.7 V (Typ.)	Active High	Auto-retry	905ANA	None	
TCKE905NL	5.7 V (Typ.)	Active High	Latched	905NL	None	
TCKE912NA	13.7 V (Typ.)	Active High	Auto-retry	912NA	None	
TCKE912NL	13.7 V (Typ.)	Active High	Latched	912NL	None	
TCKE920NA	22.2 V (Typ.)	Active High	Auto-retry	920NA	None	
TCKE920NL	22.2 V (Typ.)	Active High	Latched	920NL	None	
TCKE903QNA	3.87 V (Typ.)	Active High	Auto-retry	903QNA	Yes	
TCKE905QNA	5.7 V (Typ.)	Active High	Auto-retry	905QNA	Yes	

5. Block Diagram

TCKE9xxNA/NL/ANA
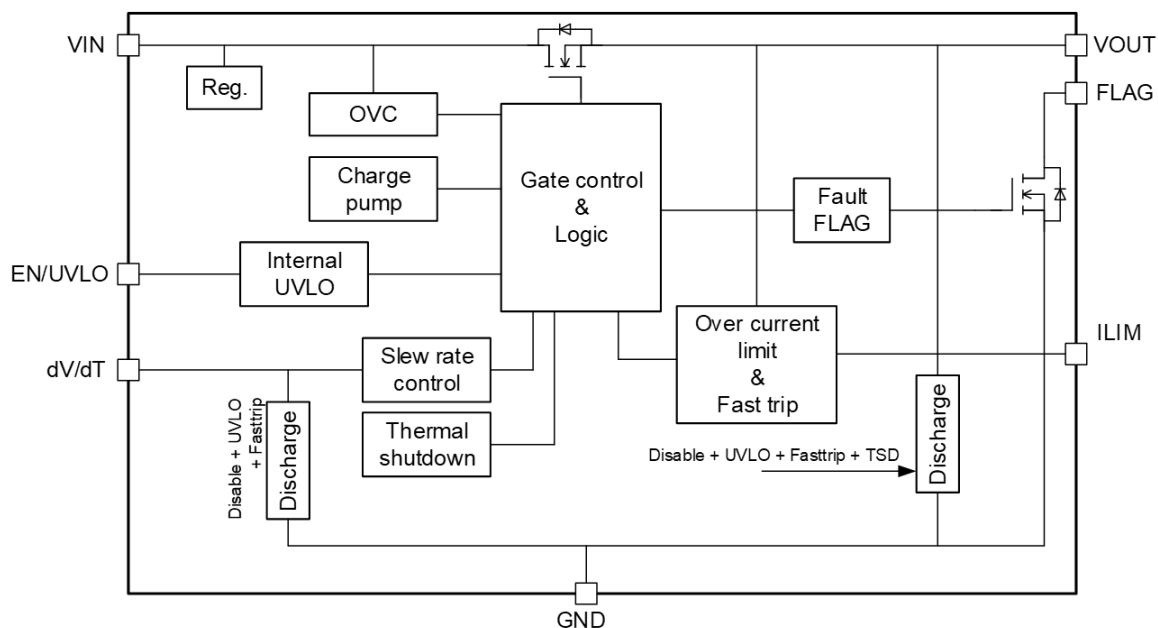
TCKE9xxQNA
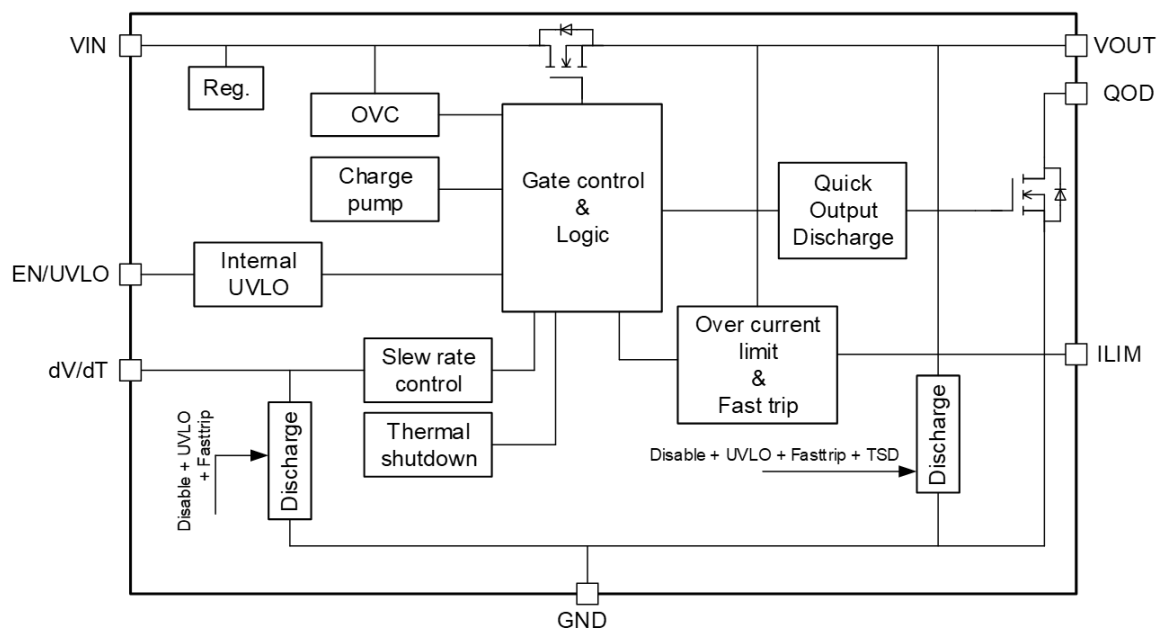
6. PIN Description

PIN Name	Description
EN/UVLO	This pin has two functions. One function turns on the output voltage of the internal MOSFET as an enable signal. Another function can be used as a UVLO trip point with external resistors.
ILIM	Current limit set input. A resistor between ILIM pin and GND sets the current limit.
dV/dT	Rise time set input. A capacitor between dV/dT pin and GND sets the slew rate of VOUT when the device turns on.
FLAG	FLAG Open-Drain output pin. Fault event indicator which is pulled low when a fault is detected.
QOD	Quick output discharge pin when connected between VOUT and QOD directly or through external resistor.
VIN	Supply Input. Input to the power switch and the supply voltage for the device.
GND	Ground.
VOUT	Output. Output of the power switch.

Exposed Pad has to be connected to GND pattern because of stability operation and heat radiation.

7. Operation Logic Table

$V_{IN\_UVLOR} \leq V_{IN} \leq 23.0$ V, Ta = -40 to 125 ºC

TCKE9xxNA/NL/ANA

	EN/UVLO = Low level	EN/UVLO = High level
Output	**OFF**	**ON**

TCKE9xxQNA

	EN/UVLO = Low level	EN/UVLO = High level
Output	OFF	ON
Quick output discharge	ON	OFF

8. Electrical Characteristics

8.1. DC Characteristics 1

(Unless otherwise specified, T_a = -40 to 125 °C, V_{IN} = 3.3 V (TCKE903), V_{IN} = 5 V (TCKE905),
V_{IN} = 12 V (TCKE912), V_{IN} = 20 V (TCKE920), R_{ILIM} = 487 Ω)

Characteristics	Symbol	Test Condition		T_a = 25 °C			T_a = -40 to 125 °C (Note2)		Unit
				Min	Typ.	Max	Min	Max	
Basic operation									
VIN under voltage lockout (UVLO) threshold	V_{IN_UVLOR1}	Rising, TCKE9xx series		—	2.51	—	2.35	2.68	V
	V_{IN_UVLOF1}	Falling, TCKE9xx series		—	2.41	—	2.25	2.53	V
	V_{IN_UVLOR2}	Rising, TCKE9xxQ series		—	2.80	—	2.63	2.97	V
	V_{IN_UVLOF2}	Falling, TCKE9xxQ series		—	2.68	—	2.52	2.81	V
EN/UVLO threshold voltage rising	V_{ENUVR}	—		—	1.20	—	1.13	1.27	V
EN/UVLO threshold voltage falling	V_{ENUVF}	—		—	1.10	—	1.03	1.17	V
EN/UVLO leak current	I_{ENUVL}	V_{IN} = 25 V, EN = 0 V		—	0	—	-0.1	0.1	μA
On resistance (Note 4)	R_{ON}	I_{OUT} = 1.5 A, $V_{IN} \geq$ 4 V		—	34	37	—	52	mΩ
		I_{OUT} = 1.5 A, 2.7 V ≤ V_{IN} < 4 V (Note 7)		—	36.0	40.0	—	55.3	mΩ
Quiescent current (ON state)	I_Q	V_{EN} = 3 V, R_{ILIM} = 487 Ω, I_{OUT} = 0 A	TCKE903	—	180	—	—	250	μA
			TCKE905	—	180	—	—	250	μA
			TCKE912	—	185	—	—	250	μA
			TCKE920	—	190	—	—	250	μA
Quiescent current (OFF state)	$I_{Q(OFF)}$	V_{EN} = 0 V, $V_{IN} \leq$ 5 V (Note 3)		—	0.07	—	—	—	μA
		V_{EN} = 0 V, 5 V < $V_{IN} \leq$ 18 V		—	1.20	—	—	2.55	μA
		V_{EN} = 0 V, 18 V < $V_{IN} \leq$ 21 V TCKE920NA / NL only		—	1.20	—	—	2.55	μA
FLAG									
FLAG pin resistance	R_{FLAG}	Low Level (Note 3)		—	12	—	—	—	Ω
FLAG Leak current	I_{FLAG}	V_{FLAG} = 6 V		—	—	—	—	0.1	μA

Note 2: This parameter is warranted by design.
Note 3: This parameter is reference only.
Note 4: Pulsed testing techniques used during this test maintain junction temperature approximately
equal to ambient temperature.
Note 7: 3 V ≤ V_{IN} < 4 V (TCKE9xxQNA)

8.2. DC Characteristics 2

(Unless otherwise specified, T_a = -40 to 125 °C, V_{IN} = 3.3 V (TCKE903), V_{IN} = 5 V (TCKE905), V_{IN} = 12 V (TCKE912), V_{IN} = 20 V (TCKE920), R_{ILIM} = 487 Ω)

Characteristics	Symbol	Test Condition		T_a = 25 °C			T_a = -40 to 125 °C (Note.2)		Unit
				Min	Typ.	Max	Min	Max	
Over-voltage Protection									
Over-voltage clamp (OVC) Threshold voltage	V_{OVC}	TCKE903	R_{OUT} = 10 kΩ	—	3.87	—	3.64	4.1	V
		TCKE905		—	5.7	—	5.4	6.0	V
		TCKE912		—	13.7	—	13.2	14.3	V
		TCKE920		—	22.2	—	21.0	23.3	V
Output voltage at Over-voltage clamped	V_{CLAMP}	TCKE903	I_{OUT} = 10 mA	—	3.60	—	3.45	3.87	V
		TCKE905		—	5.55	—	5.20	5.80	V
		TCKE912		—	13.55	—	13.00	14.10	V
		TCKE920		—	22.1	—	21.0	22.8	V
OVC response time (Note 3)	t_{OVC}	I_{OUT} = 4 A		—	6.0	—	—	—	µs
		I_{OUT} = 100 mA		—	9.0	—	—	—	µs
Over-current Protection									
Overcurrent limit (Note 4)	I_{LIM} (I_{OUT_CL})	R_{ILIM} = 487 Ω		—	4.09	—	3.40	4.68	A
		R_{ILIM} = 1780 Ω		—	1.11	—	0.95	1.36	
		R_{ILIM} = 4420 Ω		—	0.49	—	0.33	0.65	
		R_{ILIM} = 0 Ω (Note 3)		—	2	—	—	—	
		R_{ILIM} = OPEN (Note 3)		—	0	—	—	—	
Current monitor gain as measured on ILIM pin (I_{LIM}/I_{OUT}) (Note5)	G_{IMON}	I_{OUT} = 4 A, V_{IN} ≥ 4 V		—	290	—	255	326	µA/A
		I_{OUT} = 4 A, 2.7 V ≤ V_{IN} < 4 V (Note 7)		—	285	—	252	316	µA/A
		I_{OUT} = 1 A, V_{IN} ≥ 4 V		—	—	—	247	325	µA/A
		I_{OUT} = 1 A, 2.7 V ≤ V_{IN} < 4 V (Note 7)		—	—	—	245	320	µA/A
Fast trip comparator level (Note 3)	I_{SHORT}	—		—	I_{LIM} × 1.6	—	—	—	A
ILIM pin short resistor detect Threshold (Note 3)	$R_{SHORTLIM}$			—	100	—	—	—	Ω
Short circuit response time (Note 3)	t_{SHORT}			—	2.0	—	—	—	µs
Current limit response time (Note 3)	t_{LIM}			—	80	—	—	—	µs
Thermal shutdown Protection (Note 3)									
Thermal shutdown Threshold	T_{SD}	T_j		—	155	—	—	—	°C
Thermal shutdown Hysteresis	T_{SDH}	T_j		—	20	—	—	—	°C
Thermal shutdown Auto-retry Interval	$t_{TSD, RST}$	—		—	55	—	—	—	ms
Quick output discharge									
Discharge resistance	R_{QOD}	TCKE9xxQ series		—	12	—	—	—	Ω

Note 2: This parameter is warranted by design.
Note 3: This parameter is reference only.
Note 4: Pulsed testing techniques used during this test maintain junction temperature approximately
  equal to ambient temperature.
Note 5: Without OVC operation.
Note 7: 3 V ≤ V_{IN} < 4 V (TCKE9xxQNA)

2025-05-20
Rev.9.0

8.3. AC Characteristics

(Unless otherwise specified, T_a = 25 °C, R_{ILIM} = 487 Ω, R_{LOAD} = 100 Ω, C_{IN} = C_{OUT} = 1 μF)

Characteristics	Symbol	Test Condition		Min	Typ.	Max	Unit
Turn on delay (Note 3)	$t_{D,ON}$	$C_{dV/dT}$ = OPEN (Note 6)	V_{IN} = 3.3 V	—	181	—	μs
			V_{IN} = 5 V	—	183	—	μs
			V_{IN} = 12 V	—	197	—	μs
			V_{IN} = 20 V		216		
		$C_{dV/dT}$ = 3300 pF	V_{IN} = 3.3 V	—	240	—	μs
			V_{IN} = 5 V	—	250	—	μs
			V_{IN} = 12 V	—	310	—	μs
			V_{IN} = 20 V		394		
Turn off delay (Note 3)	$t_{D,OFF}$	$C_{dV/dT}$ = OPEN (Note 6)	V_{IN} = 3.3 V	—	9.0	—	μs
			V_{IN} = 5 V	—	8.9	—	μs
			V_{IN} = 12 V	—	8.7	—	μs
			V_{IN} = 20 V		7.3		
		$C_{dV/dT}$ = 3300 pF	V_{IN} = 3.3 V	—	9.2	—	μs
			V_{IN} = 5 V	—	9.0	—	μs
			V_{IN} = 12 V	—	8.8	—	μs
			V_{IN} = 20 V		7.6		
VOUT rise time (Note 3)	t_r	$C_{dV/dT}$ = OPEN (Note 6)	V_{IN} = 3.3 V	—	142	—	μs
			V_{IN} = 5 V	—	180	—	μs
			V_{IN} = 12 V	—	353	—	μs
			V_{IN} = 20 V		673		
		$C_{dV/dT}$ = 3300 pF	V_{IN} = 3.3 V	—	238	—	μs
			V_{IN} = 5 V	—	366	—	μs
			V_{IN} = 12 V	—	915	—	μs
			V_{IN} = 20 V		1437		
Output Rising Slew Rate (Note 3)	SRon	$C_{dV/dT}$ = OPEN (Note 6)	V_{IN} = 3.3 V	—	18.6	—	V/ms
			V_{IN} = 5 V	—	22.2	—	V/ms
			V_{IN} = 12 V	—	27.1	—	V/ms
			V_{IN} = 20 V		24.0		
		$C_{dV/dT}$ = 3300 pF	V_{IN} = 3.3 V	—	11.0	—	V/ms
			V_{IN} = 5 V	—	11.0	—	V/ms
			V_{IN} = 12 V	—	11.0	—	V/ms
			V_{IN} = 20 V		11.0		

Note 3: This parameter is reference only.
Note 6: If $C_{dV/dT}$ = OPEN and there is a load at boot time, booting may not be completed.
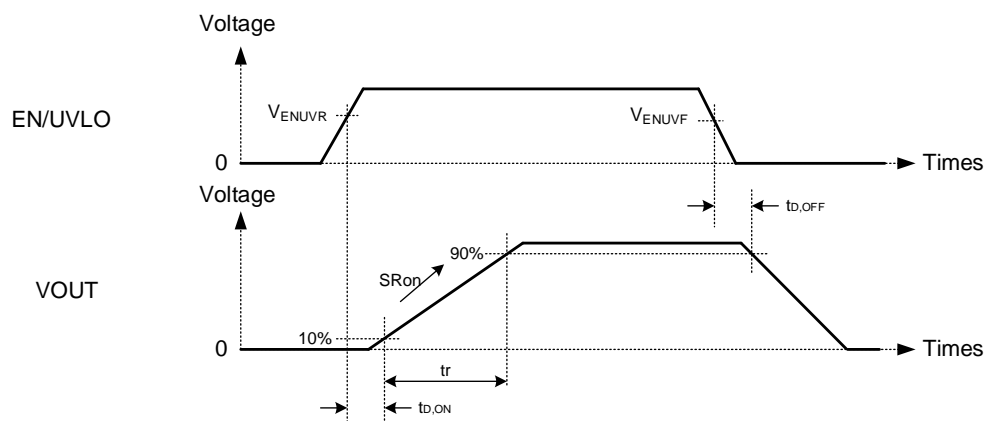
9. Function Explanation

9.1. Inrush current reduction

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 may malfunction, making it impossible to start up, or the output voltage may overshoot.

To prevent this, this function controls the slew rate when the output voltage rises for limiting the inrush current.

The following figure shows the rise of the output voltage (V_{OUT}) and the inrush current when the inrush current is limited by this function.
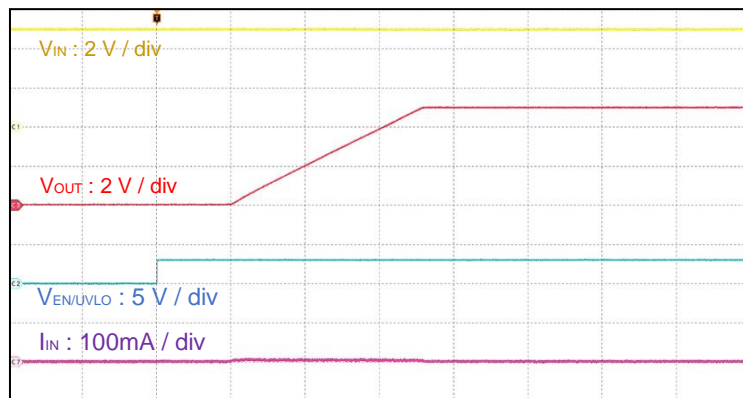
9.1.1. Setting of slew rate control for inrush current reduction

Toshiba eFuse IC has a variable inrush current function. The external capacitor at the dV/dT pin can be used to appropriately set the rise time Slew rate (SRon) of the output voltage. The formula for the rise time is as follows.

$$SRon \left(\frac{V}{ms} \right) = \frac{I_{INRUSH} \ (mA)}{C_{OUT} \ (\mu F)}$$

$$C_{dV/dT} \ (pF) = \frac{42000}{SRon \left(\frac{V}{ms} \right)}$$
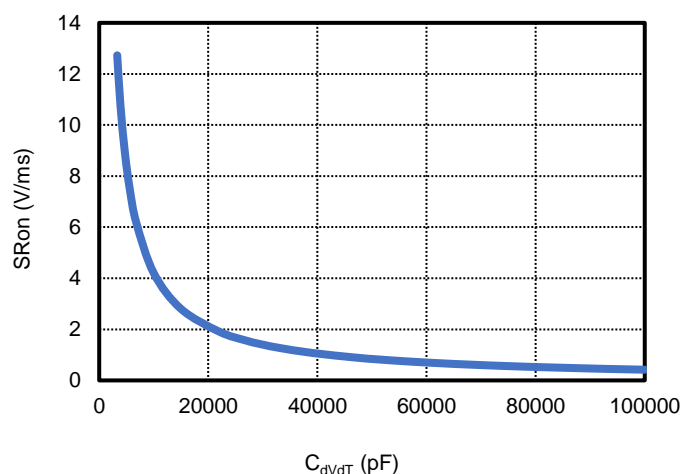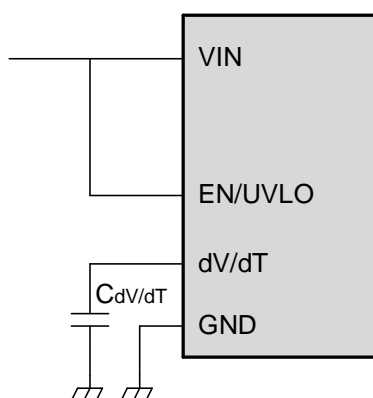
External Circuits around dV/dT pin

9.2. VIN Under voltage lockout function (VIN UVLO)

This function stops eFuse IC operation at low input voltage to prevent load malfunction.

The TCKE9 series starts operation when the input voltage (V_{IN}) exceeds a certain voltage. This voltage has hysteresis at the rising and falling voltages, and operation stops when the voltage drops below a certain level.
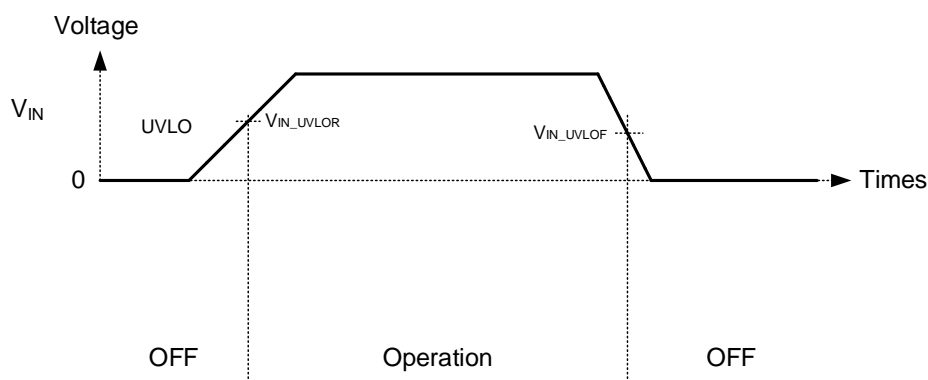
9.3. EN/UVLO Operation

The TCKE9 series is equipped with EN/UVLO pin, and this pin can be used to control the operation of the whole eFuse IC. It is also possible to set the operating voltage of the UVLO function to the optimum value by externally attaching a resistor. The following are examples of uses for this pin.

9.3.1. When the operation voltage of the UVLO function is not changed or the operation control is not performed.
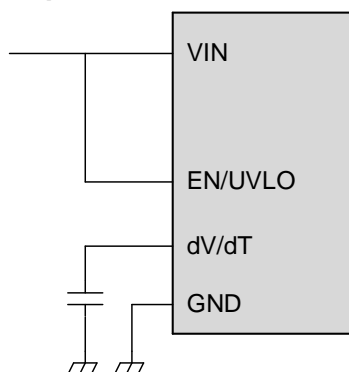
Connect the EN/UVLO pin directly to the VIN pin. This eliminates the need for pull-up resistors in the TCKE9 series. The EN/UVLO pin is designed to be breakdown-voltage 25 V, and the VIN pin and the EN/UVLO pin can be directly connected. This helps reduce the number of parts.

Connections of EN/UVLO pin (Direct VIN connection)

9.3.2. When the operation voltage of the UVLO function is not changed and the operation control is performed from the outside.
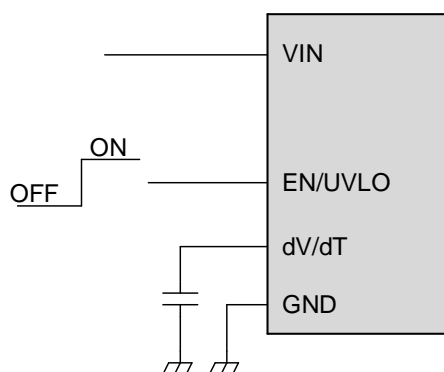
Connect external control signals directly into the EN/UVLO pin. Since the on/off threshold voltages of the EN/UVLO pin s are hysteretic, set the High level of the control signal to be 1.2 V (Typ.) or higher and the Low level of the control signal to be 1.1 V (Typ.) or lower.

If the EN/UVLO pin is open (indefinite), the eFuse IC operation may become abnormal. Be careful not to open this pin even when it is at the Low level.

Connections of EN/UVLO pin (External control signals**)**

9.3.3. When the operation voltage of the UVLO function is not changed and the operation is controlled by the short-circuit switch with the VIN pin
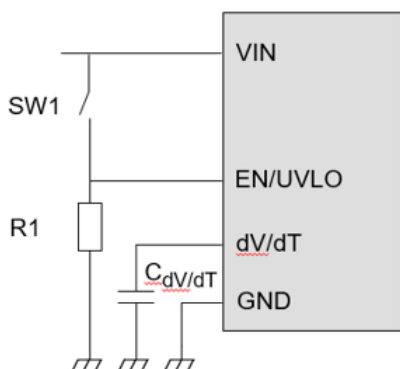
Switches can be directly connected to the VIN pin so that the operation can be controlled. A pull-down resistor is required to prevent the EN/UVLO pin from being opened when the SW1 is opened. The value of the pull-down resistor may be any value that does not cause the EN/UVLO pin to become indefinite. However, when the SW1 is conducting, consider the current flowing through R1, and check the value with the actual device to determine the value of the pull-down resistor.

Connection examples of EN/UVLO pin (connected by VIN and switches)

9.3.4. To change the operating voltage of the UVLO function
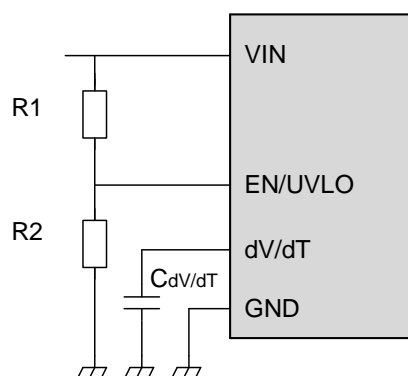
By adding an external resistor to the EN/UVLO pin, the operating voltage of the UVLO function can be changed to an optimum value. An example of the circuit is shown in the figure below.

a) When operation is not controlled by the EN/UVLO pin

Operation is stopped when the input voltage drops by controlling the operation of the EN/UVLO pin with the voltage obtained by dividing the input voltage by an external resistor. The operating voltage of the UVLO function can be set to the optimum value by properly selecting the external resistance. However, the V_{IN} voltage cannot be set to V_{IN_UVLO} threshold or less.
The equation for setting $V_{IN/UVLO(fall)}$ by controlling the external resistors R1 and R2 of the EN/UVLO pin is as follows.

a) When operation is not controlled

$$V_{IN/UVLO(fall)} \, (\, V \,)= \frac{R1+R2}{R2} \times V_{ENUVF} \, (\, V \,)$$

V_{ENUVF}: EN threshold (falling) 1.1 V (Typ.)

As described above, the control voltage of the EN/UVLO pin is hysteretic, and therefore the voltage to be activated at the time of rising changes. The start-up voltage $V_{IN/UVLO(rise)}$ is calculated by the following equation

$$V_{IN/UVLO(rise)} \, (\, V \,)= \frac{R1+R2}{R2} \times V_{ENUVR} \, (\, V \,)$$

V_{ENUVR}: EN threshold (rising) 1.2 V (Typ.)
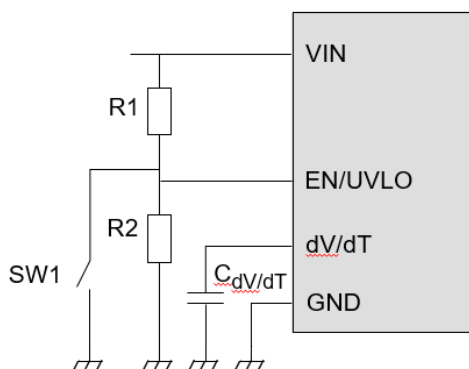
b) The circuit when the operation control is performed.

The switch can be connected in parallel with R2 to control the operation. contrary to the case of 9.3.3, the eFuse IC stops operating at the time of SW1 conduction. At this point, R1 is the current limiting resistor. Be careful when selecting the resistors for R1 and R2.

b) When operation is controlled

9.4. FLAG Output

The TCKE9xxNA/NL/ANA outputs L signal to FLAG pin in case of detecting abnormal conditions.

Failure mode	Symbol	IC Operation	FLAG output
Over temperature	TSD	Shutdown	Yes
V_{IN} Over voltage	OVC	V_{OUT} voltage clamp	—
V_{IN} Under voltage	UVLO	Shutdown	—
I_{OUT} Over current	OCL	I_{OUT} current limiting	—
V_{OUT} Short circuit	OCL	I_{OUT} current limiting	—
ILIM pin open	—	Shutdown	—
ILIM pin short (I_{OUT} > 2 A Typ.)	—	Shutdown	Yes

If a large current continues in the OVC state or if the OCL state continues, the junction temperature of the IC will rise.
If the junction temperature rises and TSD is detected, it shuts down and outputs FLAG.

9.5. Quick output discharge

The TCKE9xxQNA provides a Quick output discharge by connecting the QOD pin and VOUT pin directly or through an external resistor when the IC is turned off. The internal MOSFET turns on and drops the VOUT to 0 V. The MOSFET operates with constant current discharge in the saturation region. After the MOSFET enters the linear region, it works with resistive discharge.

The figure below shows the discharge waveforms of the TCKE9xxQNA. When the QOD pin is OPEN, the output discharge time is determined by the output capacitor and the Load. The QOD pin can be connected to the VOUT pin for the output discharge function. The output voltage discharge time is determined by the output capacitor, the total discharge path resistance (internal and external), and the Load.
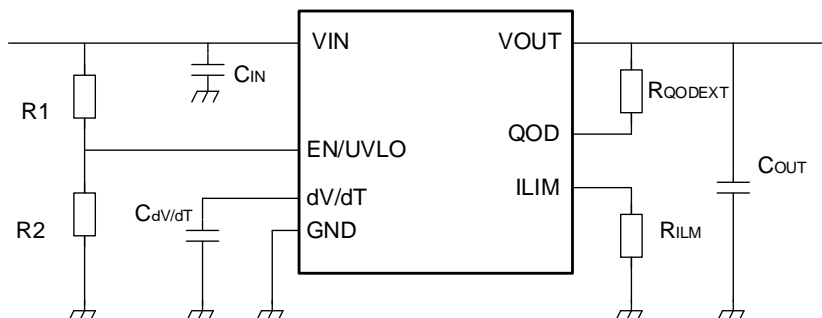
R_{QODEXT} = OPEN
V_{IN} = 5.0 V, EN = H to L, C_{OUT} = 100 μF, R_{OUT} = 1 kΩ, Ta = 25 ºC

100 msec/div
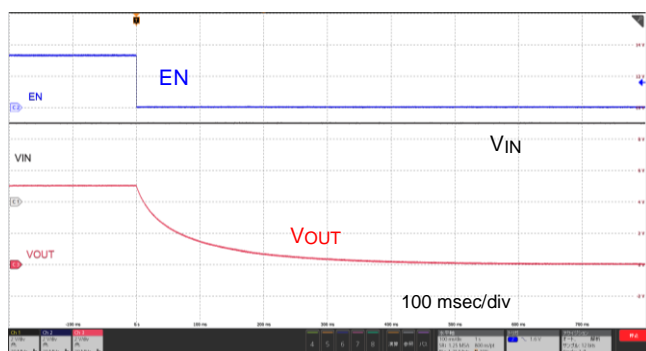
R_{QODEXT} = Short
V_{IN} = 5.0 V, EN = H to L, C_{OUT} = 100 μF, R_{OUT} = 1 kΩ, Ta = 25 ºC

4 msec/div
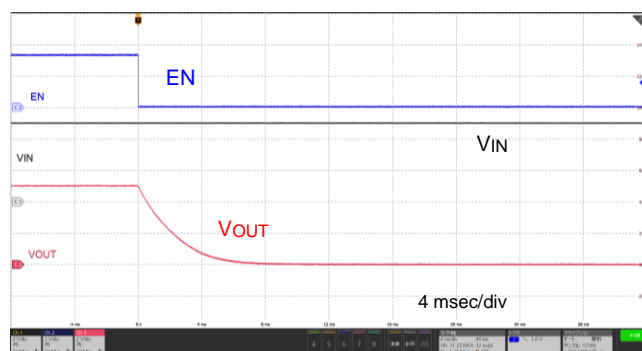
R_{QODEXT} = OPEN
V_{IN} = 3.3 V, EN = H to L, C_{OUT} = 100 μF, R_{OUT} = 1 kΩ, Ta = 25 ºC

100 msec/div
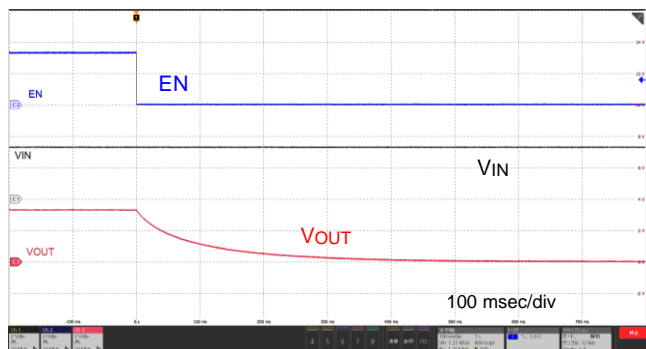
R_{QODEXT} = Short
V_{IN} = 3.3 V, EN = H to L, C_{OUT} = 100 μF, R_{OUT} = 1 kΩ, Ta = 25 ºC

4 msec/div
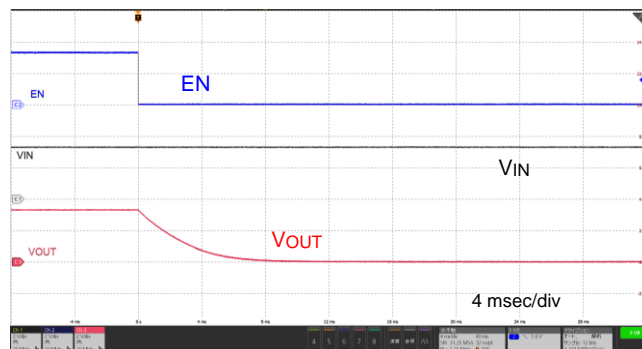
9.6. Overcurrent limit function (OCL)

The overcurrent limit function prevents damage to the IC and load by suppressing power consumption in the event of an error. If the output current exceeds the limit current (I_{LIM}) due to a load error or short circuit, the output voltage and output current also decrease, thereby limiting the power consumed by the IC and the load. In addition to the short-circuit protection function, which will be described later, it is double-protected against overcurrent, which greatly contributes to the prevention of ignition and smoke.

The figure below shows the relationship between output voltage and current during overcurrent limit function.
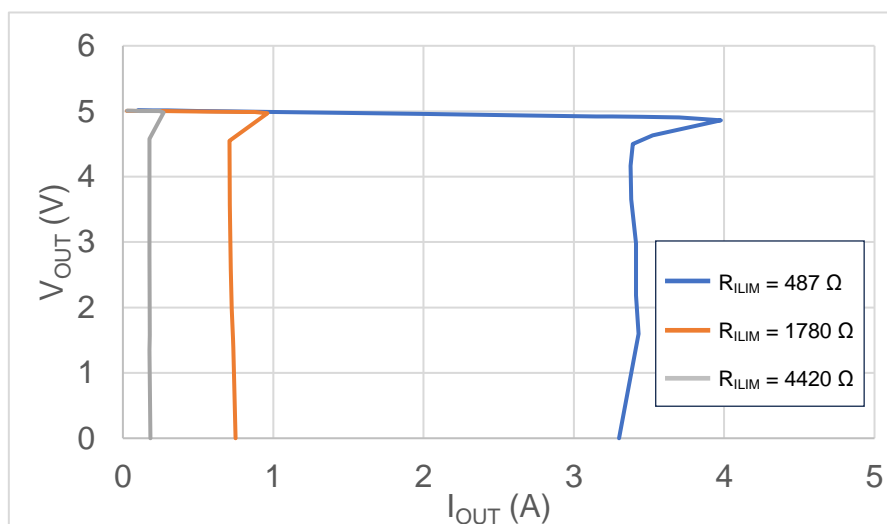
Output voltage – output current Characteristics during Overcurrent limit function

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9.6.1. Auto-retry type overcurrent protection clamping operation

When the output current value reaches the I_{LIM} and an overcurrent is detected, the current is limited so that no more current flows than the 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 IC temperature rises, and if the temperature reaches the temperature for overheat protection, the output stops and the IC goes into shutdown state. After a certain term, operation starts again, but if the overcurrent has not been resolved, the current is again limited. Therefore, the recovery attempt is repeated by the following cycle.

Current limit → temperature rise → overheat protection → shutdown → temperature drop → restart → current limit
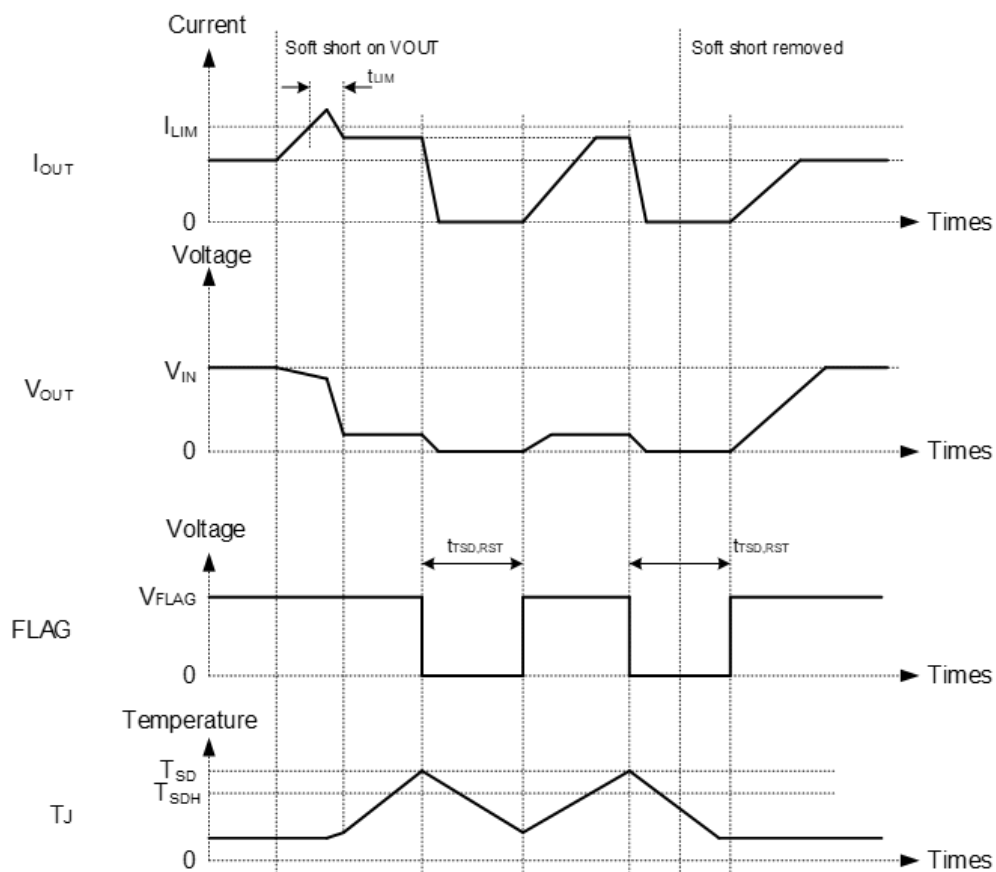
Timing chart of overcurrent protection operation (auto-retry type)

9.6.2. Latch type overcurrent protection clamping operation

In case of latch type, overheat protection operation is latched. To recover it, it must be restarted by a control signal on the EN/UVLO pin, etc. The protection operation continues until it is restarted.
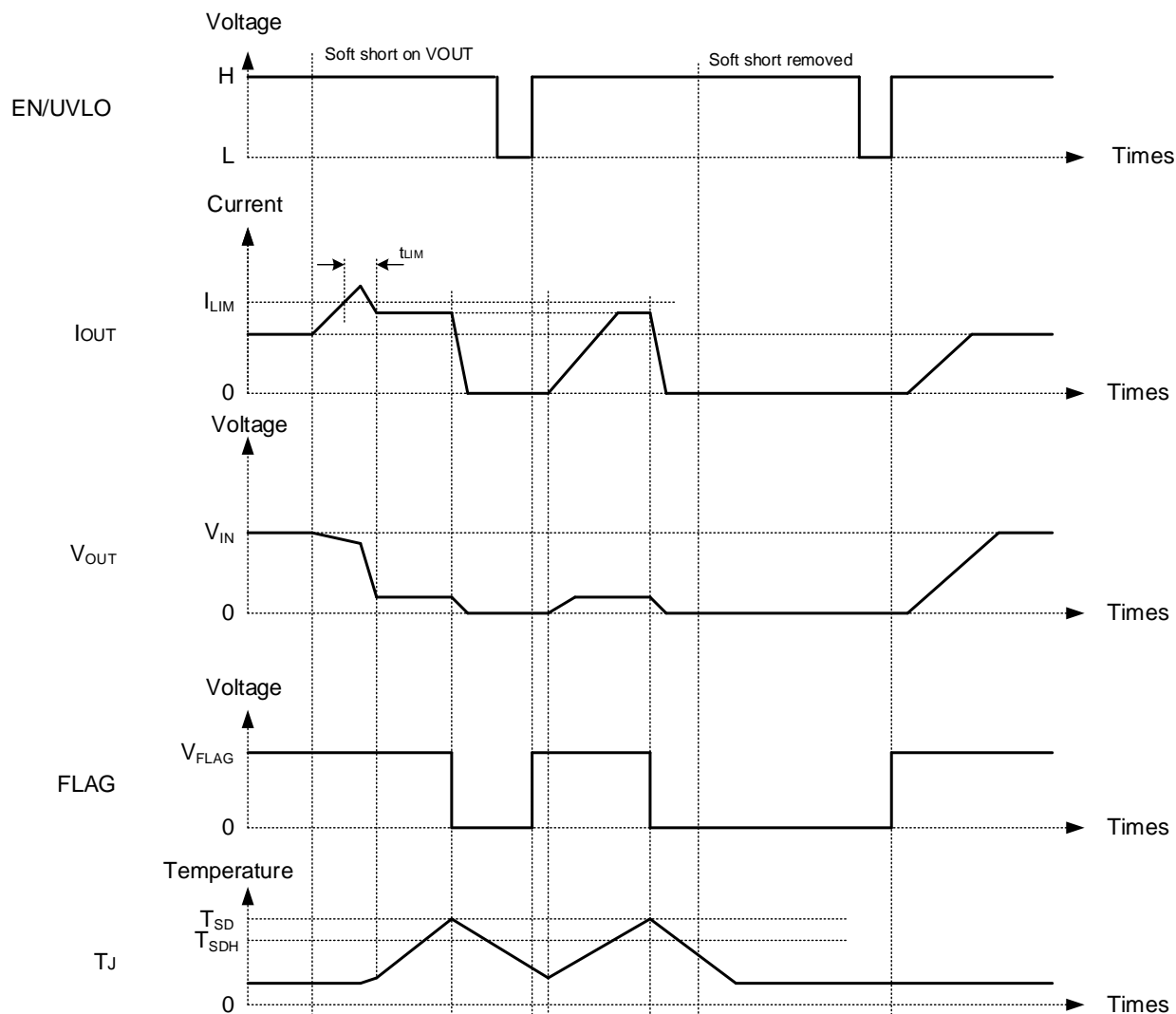
Timing chart of overcurrent protection operation (latch type)

9.6.3. Setting the overcurrent protection function

Toshiba eFuse IC has a variable current limit. By selecting the external resistor R_{ILIM} of the ILIM pin appropriately, the current limit can be set to the optimum value for each application. The I_{LIM} calculation method is common to the TCKE9 series and is shown in the figure below. However, the deviation between the theoretical value and the measured value is large when the current is 1 A or lower. Be sure to check the resistance value with the actual machine when selecting the resistance value.

Also, please make sure that R_{ILIM} does not fall below 487 Ω.

$$R_{ILIM}(\Omega) = \frac{1985}{I_{LIM}(A)-0.04}$$

R_{ILIM} : ILIM pin external resistor (Ω)

The following is a diagram of the peripheral circuitry of the ILIM pin and the relation between R_{ILIM} and I_{LIM}.

ILIM pin External Circuits
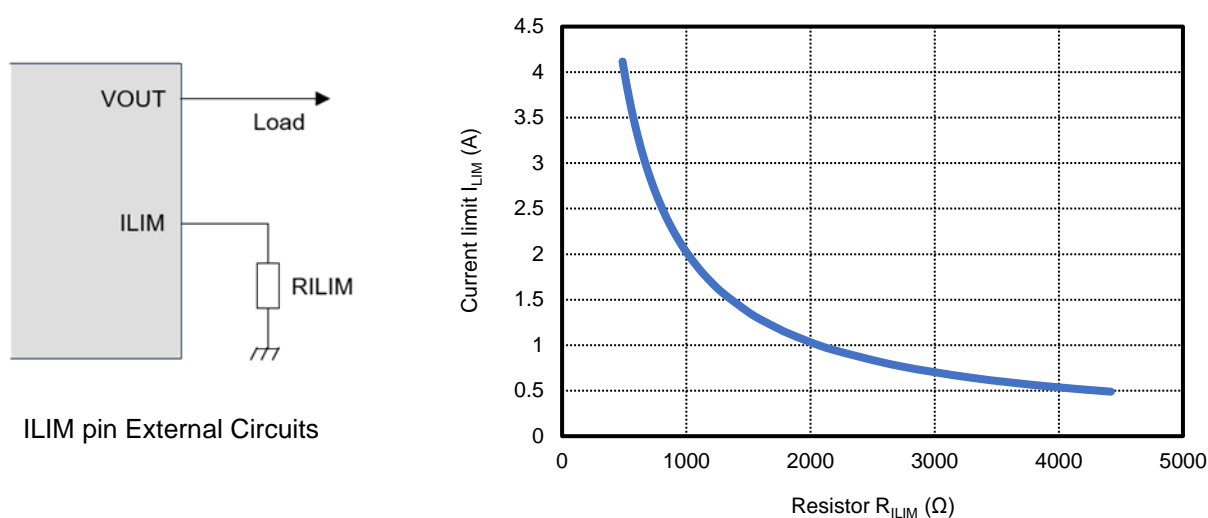
R_{ILIM} - I_{LIM} Characteristics

9.6.4. R_{ILIM} pin open protection

When the ILIM pin is open, even if EN = High level is input, the device is VOUT keeps OFF.

9.6.5. R_{ILIM} Resistor short circuit protection

If the ILIM pin voltage does not rise for a certain term from EN = High level, the IC judges that the ILIM pin is shorted to GND and shifts to the internally set current limit operation state. The internal set current limit is 2A (Typ.).

9.7. VOUT Short circuit protection (Fast trip)

The short-circuit protection function (fast trip) prevents excessive current from flowing by stopping operation when the power supply line or load is short-circuited due to some kind of abnormality. If the output current is 1.6 times the current limit (I_{LIM}) for a very short term, the output is judged to be short-circuited and this function operates.

9.7.1. Auto-retry type VOUT short-circuit protection

This function judges that VOUT is short-circuited and stops the output when the output current reaches 1.6 times the overcurrent limit current (I_{ILIM}). The IC then starts operating with soft-start operation, but if the short-circuit continues, the IC temperature rises because the over-current limit current (OCL) operation continues. After that, the overheat protection function operates and the IC goes into shutdown state. After a certain term, the IC starts operating again, but if the VOUT short circuit has not been resolved, the current is limited again. Therefore, the recovery attempt is repeated by the following cycle.

Current limit → temperature rise → overheat protection → shutdown → temperature drop → restart → current limit
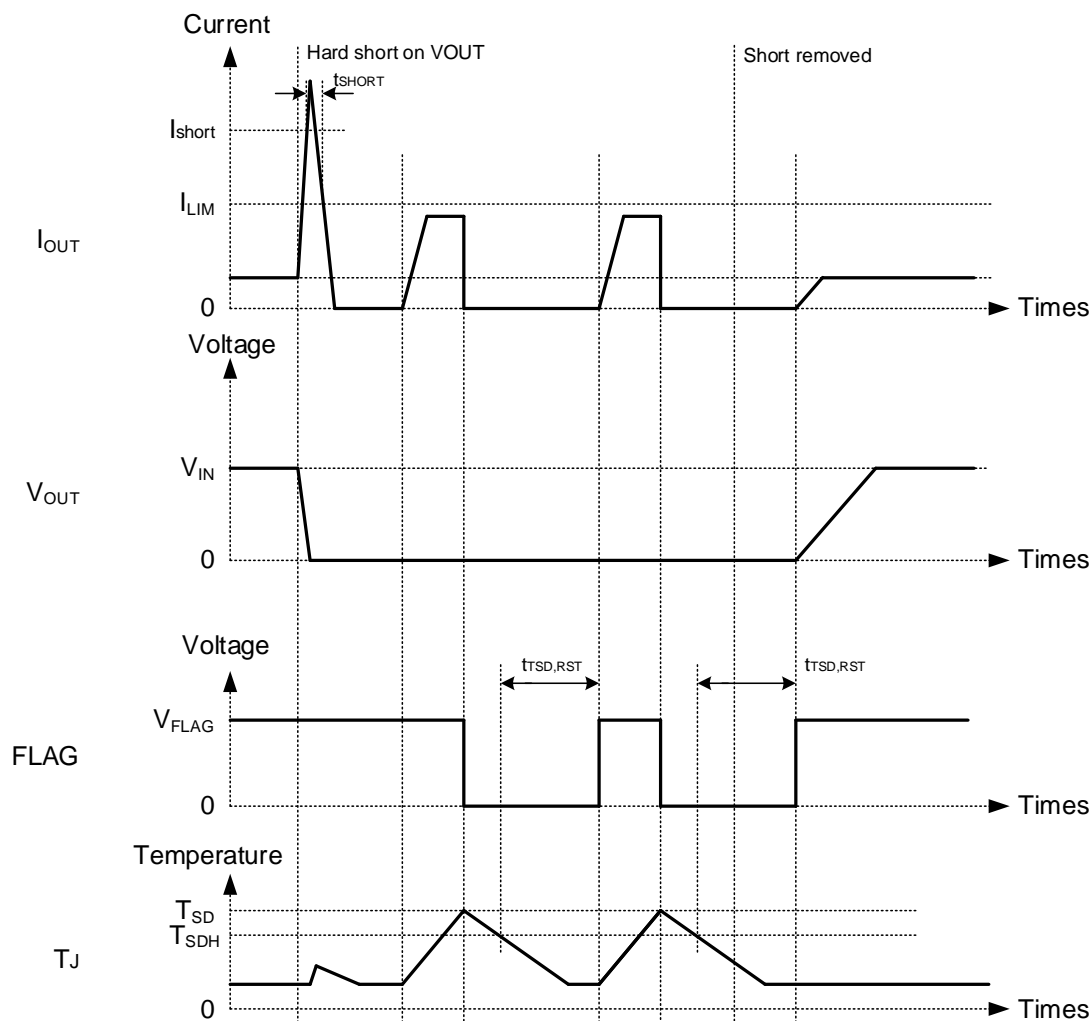
Timing chart of VOUT Short circuit protection (auto-retry type)

9.7.2. Latch type VOUT short-circuit protection

This function judges that VOUT pin is short-circuited and stops output when the output current reaches 1.6 times the overcurrent limit current (I_{LIM}).The IC then starts operating with soft-start operation, but if the short-circuit continues, the IC temperature rises as the operation continues at the overcurrent limit current (OCL). After that, the overheat protection function operates and the IC goes into shutdown state. To recover it, it must be restarted by a control signal on the EN/UVLO pin, etc. The protection operation continues until it is restarted.
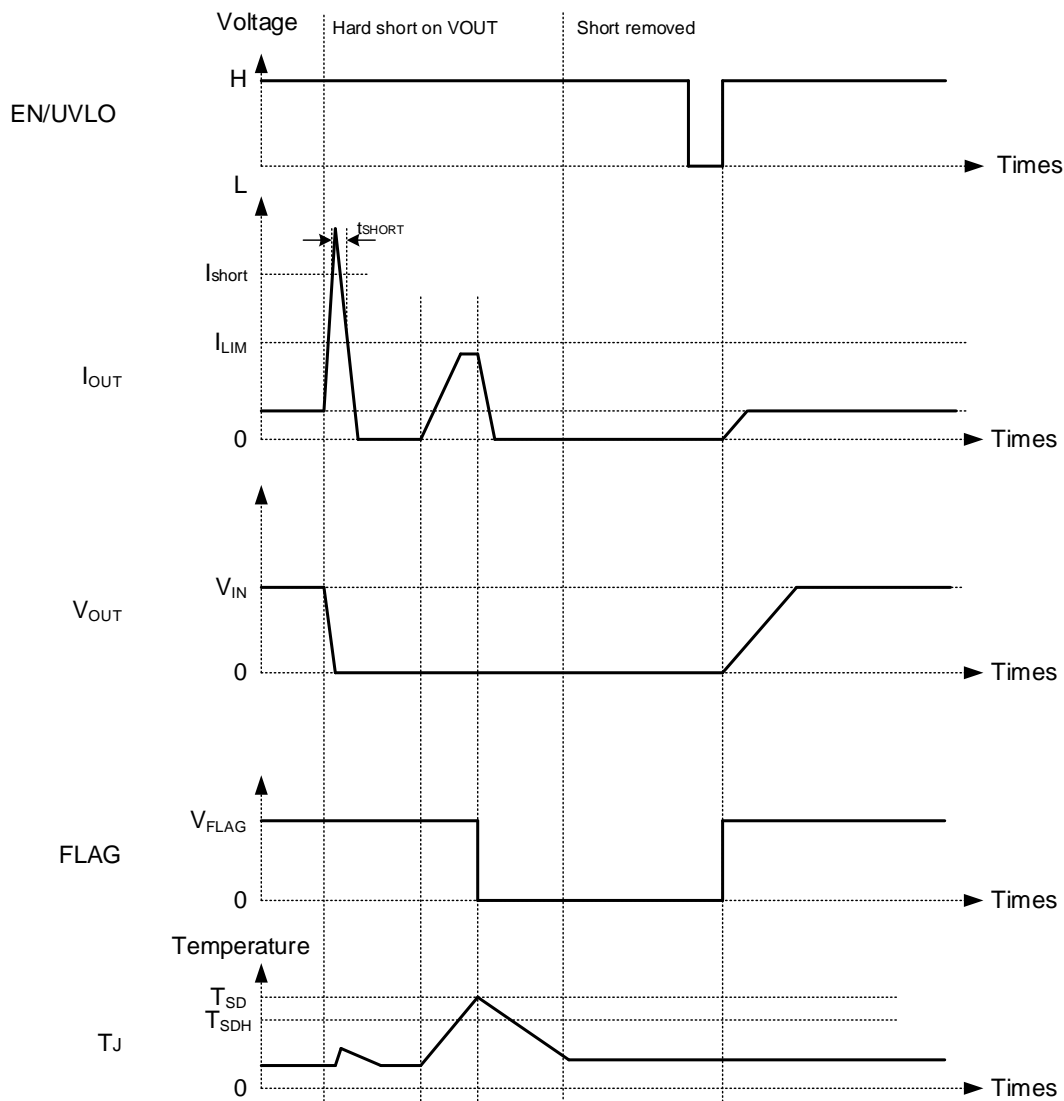
Timing chart of VOUT Short circuit protection (latch type)

9.8. Overvoltage clamp protection function (OVC)

The overvoltage clamp function clamps the output voltage with a limited voltage and prevents overvoltage from being applied to the load without outputting any more voltage. The limit voltages are set as following table.

Characteristics	Symbol	Test Condition		Ta = 25°C			Ta = -40 to 125°C (Note2)		Unit
				Min	Typ.	Max	Min	Max	
Over-voltage Protection									
Over-voltage clamp (OVC) Threshold voltage	V$_{OVC}$	TCKE903	R$_{OUT}$ = 10 kΩ	—	3.87	—	3.64	4.1	V
		TCKE905		—	5.7	—	5.4	6.0	V
		TCKE912		—	13.7	—	13.2	14.3	V
		TCKE920		—	22.2	—	21.0	23.3	V
Over-voltage clamp (OVC) Accuracy	V$_{CLAMP}$	TCKE903	I$_{OUT}$ = 10 mA	—	3.60	—	3.45	3.87	V
		TCKE905		—	5.55	—	5.20	5.80	V
		TCKE912		—	13.55	—	13.00	14.10	V
		TCKE920		—	22.1	—	21.0	22.8	V
OVC response time	t$_{OVC}$	I$_{OUT}$ = 4 A		—	6.0	—	—	—	µs
		I$_{OUT}$ = 100 mA		—	9.0	—	—	—	µs

Note 2: This parameter is warranted by design.

Similar to the overcurrent protection and short-circuit protection, the auto-retry type will attempt to recover from the overvoltage clamp, but the latch type will retain this state until it is restarted.
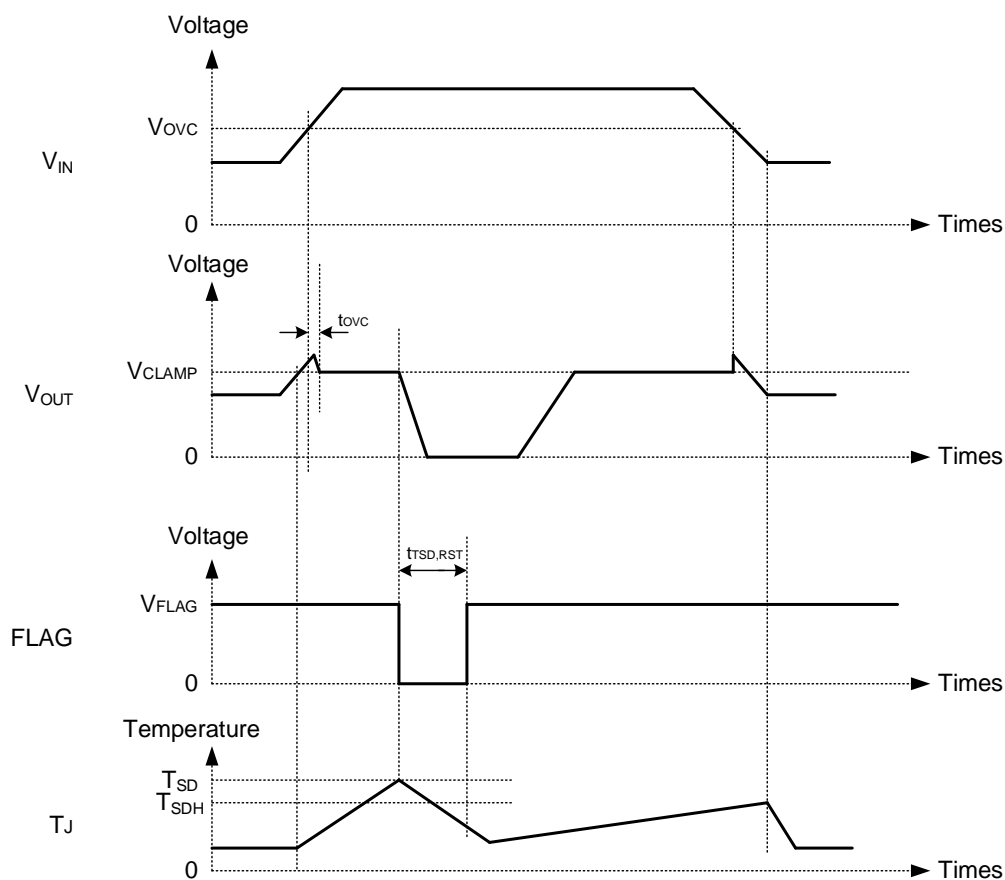
Timing chart of overvoltage clamp protection operation (auto-retry type)

9.9. Thermal shutdown protection

The overheat protection function (thermal shutdown) stops IC operation and transitions to the shutdown state when the junction temperature of the eFuse IC exceeds the set value due to continuous high current output.
The thermal shutdown protection has hysteresis between detect temperature and recover temperature.
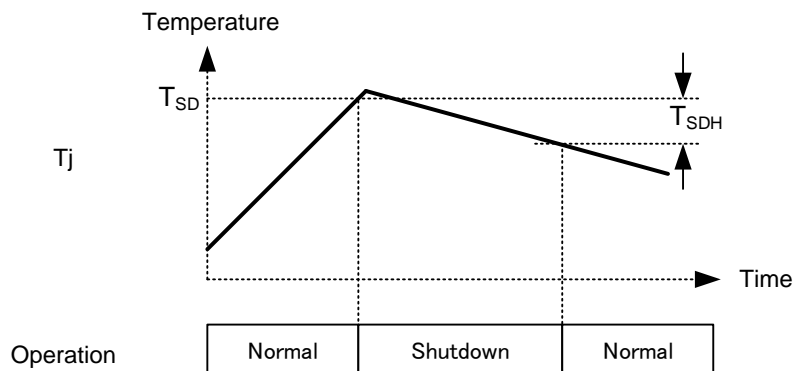
### 9.9.1. Auto-retry type Thermal shutdown

After going into a shutdown state due to overheat protection, the unit restarts after a certain term.

9.9.2. Latch type Thermal shutdown

After the overheat protection function is operated and the device goes into a shutdown state, it must be restarted by a control signal on the EN/UVLO pin, etc. to recover. The protection operation continues until restarted.

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10. Application note

10.1. Application circuit example
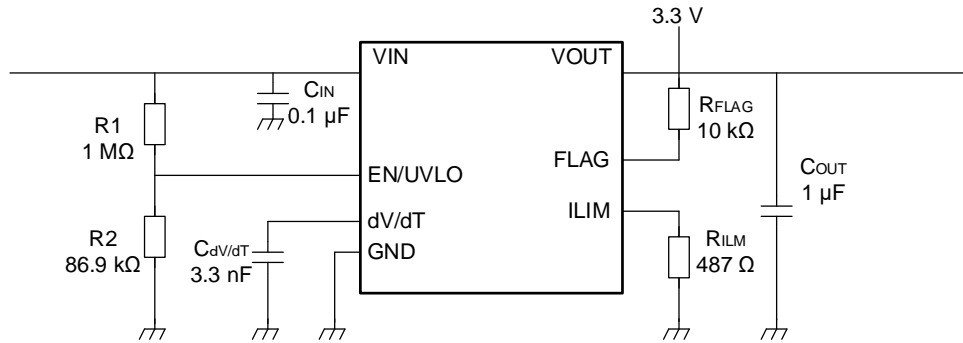
  Peripheral circuits Connect the power supply to the VIN pin. During normal operation, almost the same voltage as the VIN voltage is output from the VOUT pin through the internal MOSFET. If the current suddenly decreases, for example, when short-circuiting or overcurrent is protected, high-spike voltages may be generated due to back electromotive force of inductance components such as wirings connected to the input/output pins of the eFuse IC, causing damage to the eFuse IC and resulting destruction. In this case, a positive spike voltage is generated on the input side and a negative spike voltage is generated on the output side. When designing boards, design patterns so that the length of the wires on the input-side and output-side of the eFuse IC is as short as possible. Also, the GND wiring area should be as wide as possible to reduce the impedance. C_{IN} functions to suppress the peak value against the positive spike voltage generated by the inputs. The peak value V_{SPIKE} of the spike voltage and the capacitance value of the C_{IN} have the following relationship. It can be understood that the spike voltage can be reduced by increasing the C_{IN}.

$$V_{SPIKE} \ (V) = V_{IN} + I_{OUT} \times \sqrt{\frac{L_{IN}}{C_{IN}}}$$

> L_{IN} : effective inductance component of the input pin (H), I_{OUT} : output current (A)
> V_{SPIKE} : peak value of spiked voltage generated (V),
> V_{IN} : power supply voltage during normal operation (V)

If V_{IN} exceeds 10 V, C_{IN} is recommended to be 1 µF or more. Be sure to measure it on the actual PCB board.
If the V_{IN} voltage is high, the V_{OUT} voltage is also high, and the current change during short-circuit or overcurrent protection is large, causing unstable operation without stable V_{IN} and V_{OUT} and possibly leading to IC destruction.
If transient voltages exceeding the absolute maximum ratings are applied to the VIN pin, connect a TVS diode (ESD protection diode) or a Zener diode between the input pins and GND.
For negative spike voltages generated on the output side, such as during short-circuit protection operation, connect an SBD (Schottky barrier diode) between the output pin and GND. This will prevent the output potential from dropping significantly below GND.
SBD is effective not only for protecting eFuse ICs, but also for protecting ICs and devices connected to the load side.

As noted above, TVS diode(Zener diode) and SBD are recommended for eFuse IC because they can provide more robust protective features. The diagram below shows the peripheral circuit diagram.
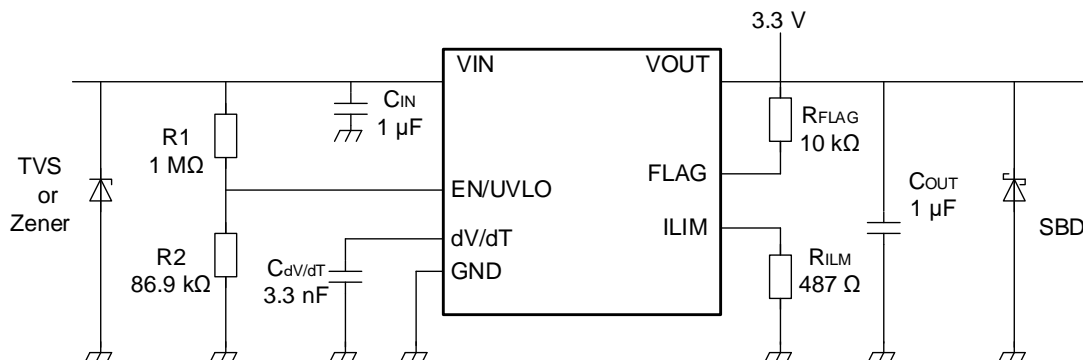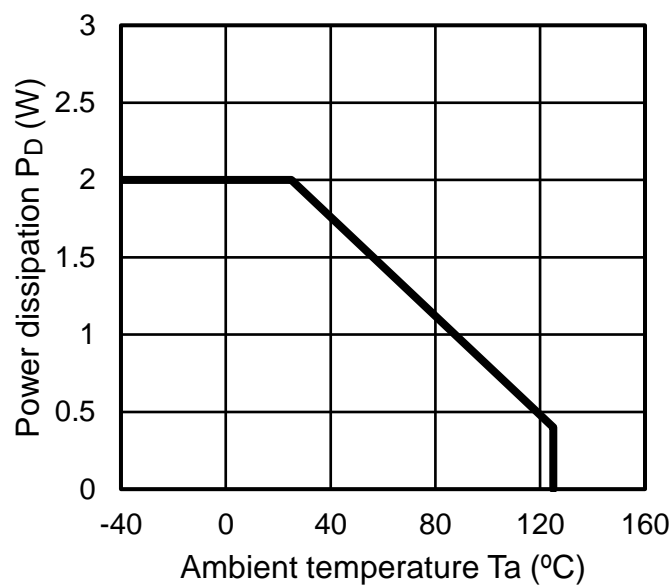
10.2. Power Dissipation

Both unit and board-mounted power dissipation ratings for TCKE9 series are available in the Absolute Maximum Ratings table.
Power dissipation is measured on the board shown below.

[The Board conditions **]**
FR4 board dimension: 76.2 mm × 114.3 mm × 1.6 mm, 4 layer

10.3. Attention in Use

● Input/Output capacitors
Ceramic capacitors can be used with the IC, however some type capacitors may have very large temperature dependence. Please consider usage environment condition carefully to select the capacitors.

● Mounting
The long distance between IC and output capacitor might affect phase assurance by impedance in wire and inductor. For stable power supply, output capacitor need to mount near IC as much as possible. Also VIN and GND pattern need to be large and make the wire impedance small as possible.

● Permissible Loss
Please have enough design patterns for expected maximum permissible loss. And under consideration of surrounding temperature, input voltage, and output current etc., we recommend proper dissipation ratings for maximum permissible loss; in general maximum dissipation rating is 70 to 80 %.

● Protection circuit
Over current protection, Over voltage protection and Thermal shut down function are designed in these products, but these are not designed to constantly ensure the suppression of the device within operation limits. Depending on the condition during actual usage, it could affect the electrical characteristic specification and reliability. Also note that if output pin pins and GND pin s are not completely shorted out, these products might be break down.
When using these products, please read through and understand the concept of dissipation for absolute maximum ratings from the above mention or our 'Semiconductor Reliability Handbook'. Then use these products under absolute maximum ratings in any condition. Furthermore, Toshiba recommend inserting failsafe system into the design.

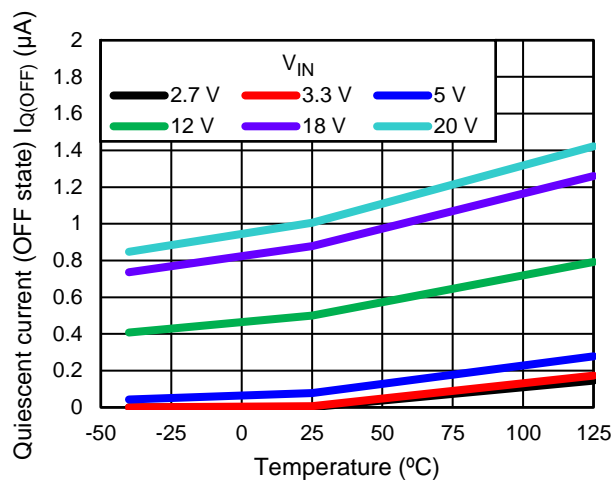# 11. Representative characteristics (Note)

Quiescent current (ON state)
V_{EN} = 3 V, R_{ILIM} = 487 Ω, I_{OUT} = 0 A
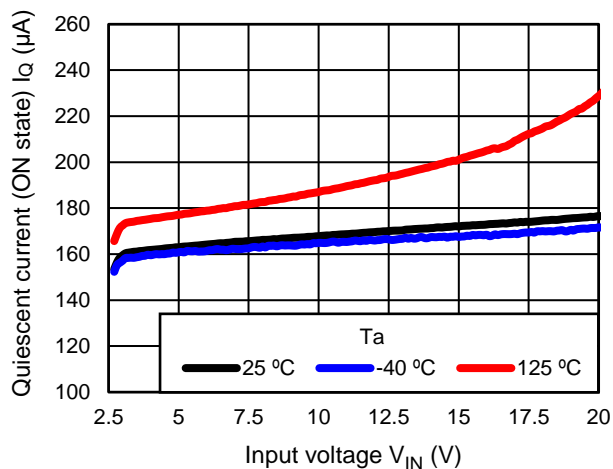
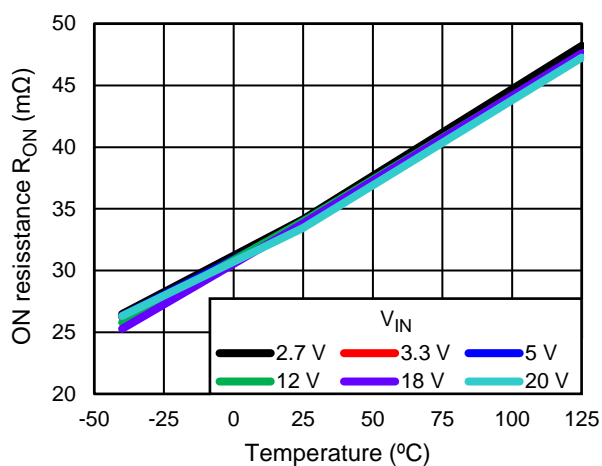### Quiescent current (OFF state)
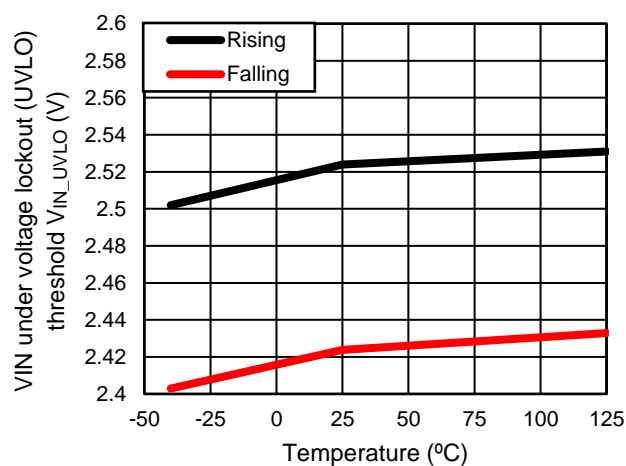V_{EN} = 0 V, R_{ILIM} = 487 Ω
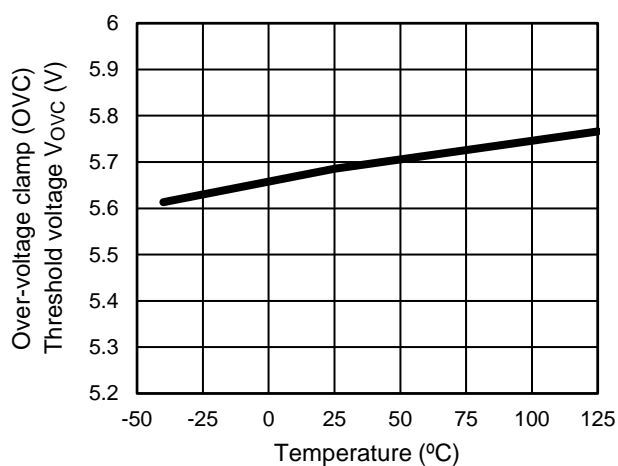

On resistance
I_{OUT} = 1.5 A

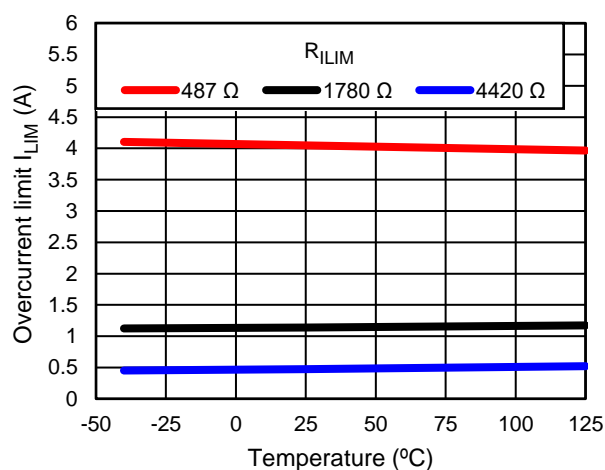### VIN under voltage lockout (UVLO) threshold
TCKE9xx series

Over-voltage clamp (OVC) Threshold voltage
TCKE905, R_{OUT} = 10 kΩ

Overcurrent limit
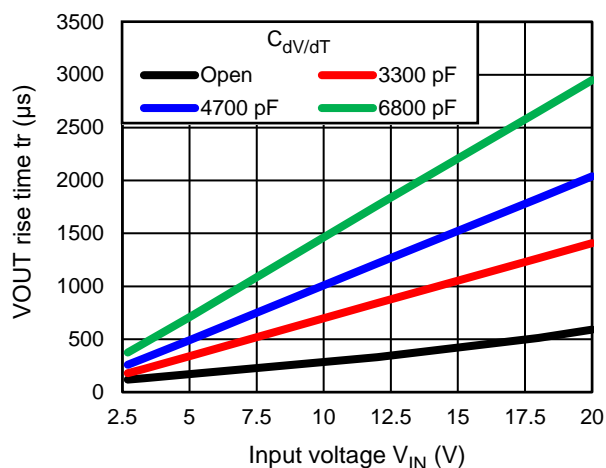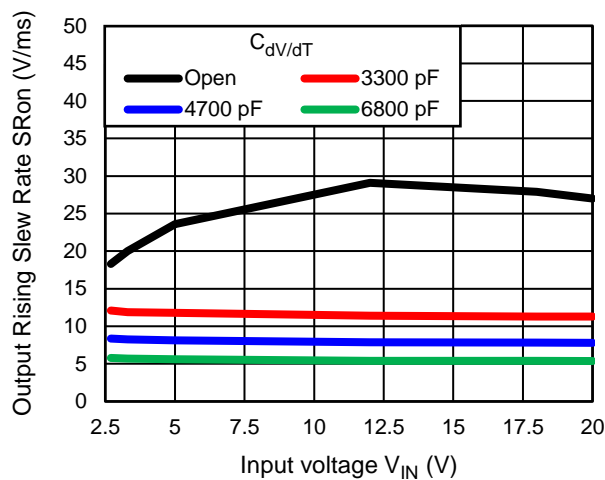V_{IN} = 12 V

VOUT rise time
Ta = 25 °C, R_{ILIM} = 487 Ω, R_{OUT} = Open

Output Rising Slew Rate
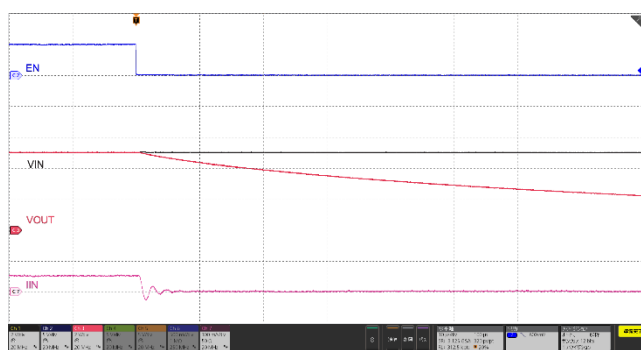Ta = 25 °C, R_{ILIM} = 487 Ω, R_{OUT} = Open

VOUT turn on
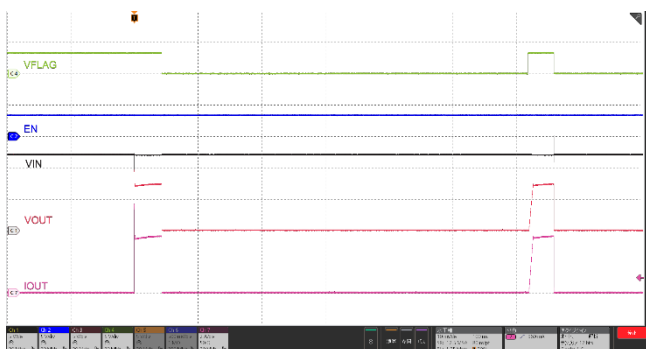V_{IN} = 5 V, C_{OUT} = 1 µF, $C_{dV/dT}$ = 3.3 nF, R_{OUT} = Open
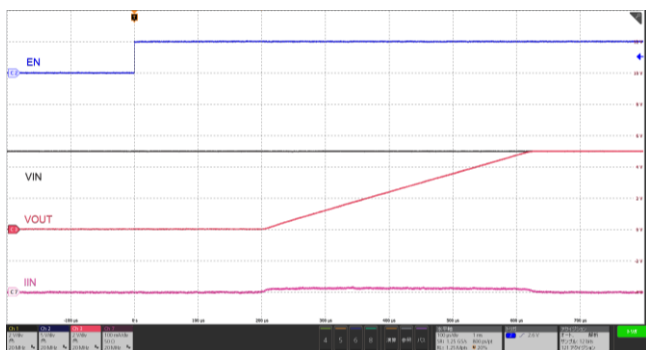
TCKE9xx series VOUT turn off
V_{IN} = 5 V, C_{OUT} = 1 µF, $C_{dV/dT}$ = 3.3 nF, R_{OUT} = 100 Ω
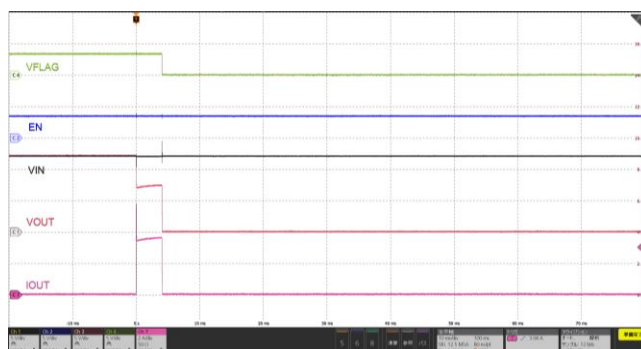

Overcurrent limit Response (Auto-retry)
V_{IN} = 12 V, C_{OUT} = 1 µF, R_{ILIM} = 487 Ω, R_{OUT} = Open to 2 Ω
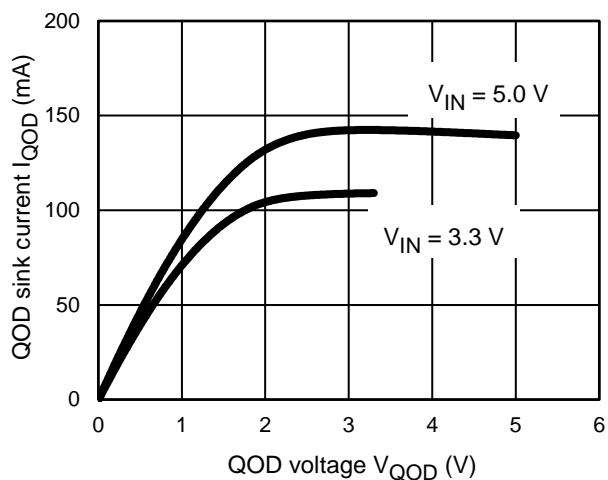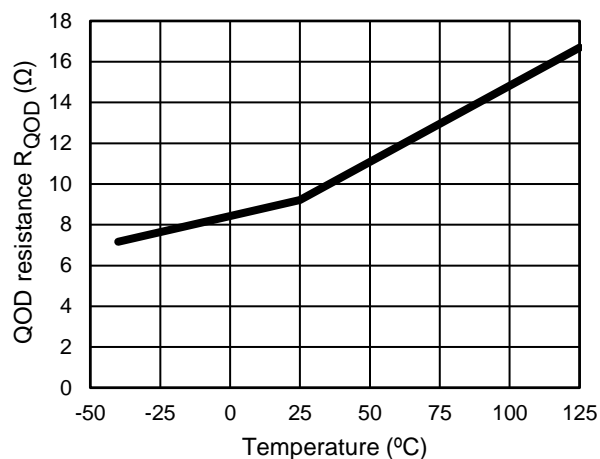

Overcurrent limit Response (Latched)
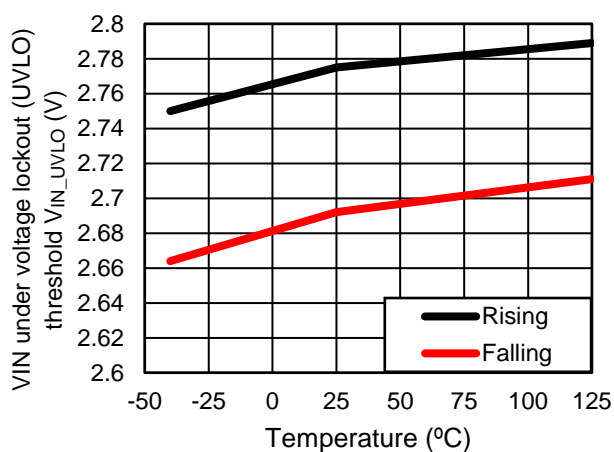V_{IN} = 12 V, C_{OUT} = 1 µF, R_{ILIM} = 487 Ω, R_{OUT} = Open to 2 Ω

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QOD sink current
V_{IN} = 3.3 V, 5.0 V, Ta = 25 ºC

QOD resistance R_{QOD}
V_{IN} = 5.0 V, IQOD = 10 mA

VIN under voltage lockout (UVLO) threshold
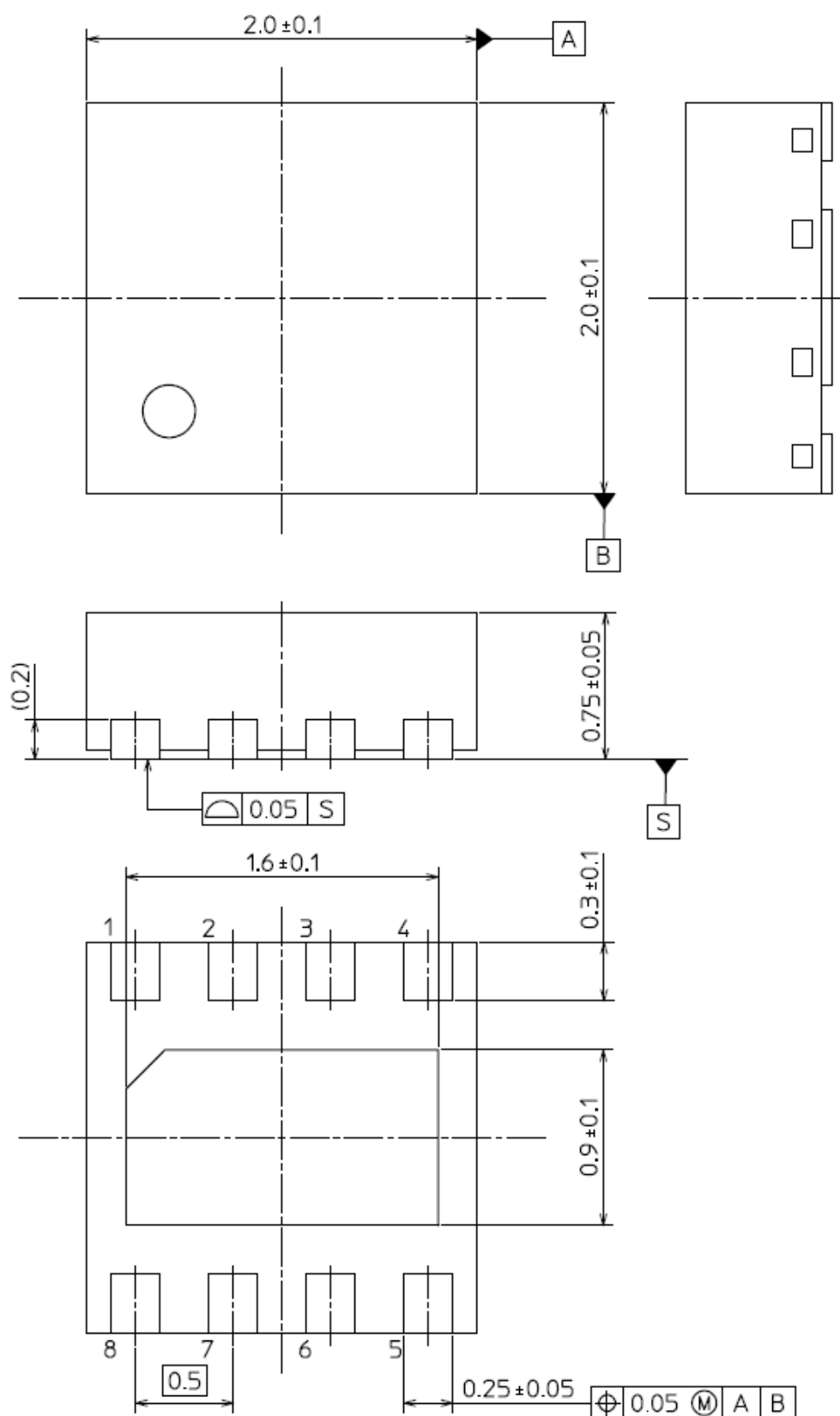TCKE9xxQ series

Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

12. Package Information

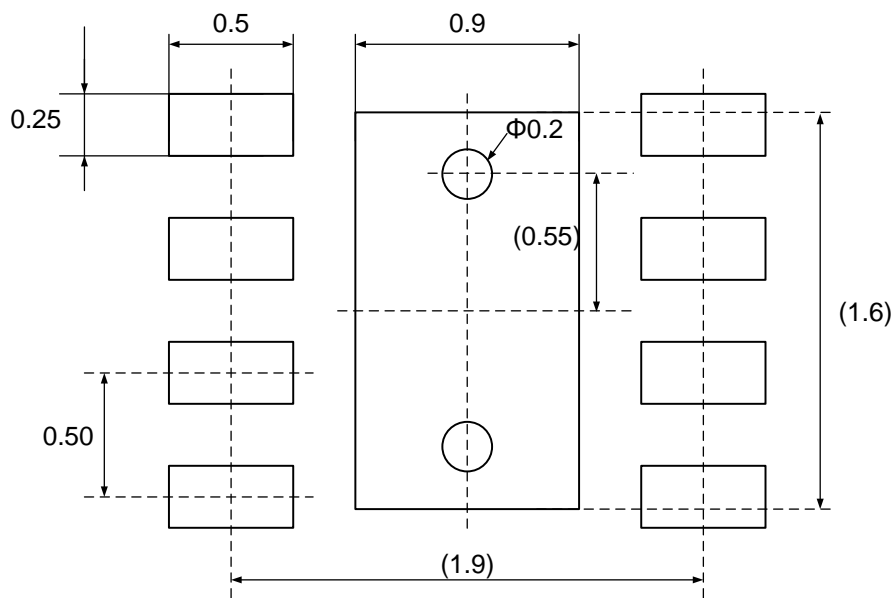WSON8   Unit: mm

Weight: 7.99 mg (Typ.)

13. Land Pattern Dimensions (for reference only)

Unit: mm

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