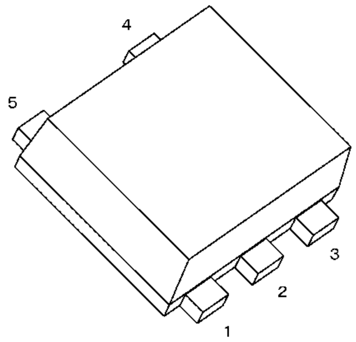
TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

TCKE5 Series

6 V, 1 A eFuse IC with Adjustable Overcurrent Protection.

1. Description

The TCKE5 Series is a single-input, single-output eFuse IC that accepts line-voltage inputs from 1.8 V to 5.0 V. It can be used as a reusable fuse and provides protective functions such as adjustable overcurrent protection using an external resistor, short-circuit protection, and overheat protection. The low on-resistance is 75 mΩ (Typ.), and the output current is available up to 1.0 A.
The device is packaged in a small UFV package (2.0 mm × 2.1 mm × 0.7 mm), making it ideal for applications that require high-density mounting, such as portable devices.



UFV (SOT-353F)

Weight: 7.2 mg (Typ.)

2. Application

Notebook PC, Mobile devices, Home appliances, Industrial equipment, etc.

3. Features

- Input voltage (Max): 6 V
- Input voltage operating range: 1.7 V to 5.5 V
- Low ON resistance: 75 mΩ (Typ.)
- Overcurrent protection
  Adjustable threshold: 0.2 A to 1.0 A (Typ.)
  Mask time 2.4 ms (Typ.)
- Short circuit protection
- Thermal shutdown
- Slew rate control
- Output Auto-discharge
- Small package: UFV (SOT-353F) (2.0 mm × 2.1 mm × 0.7 mm)

Start of commercial production
2026-06

4. Absolute Maximum Rating (Ta = 25 °C)

Table 4.1 Absolute Maximum Rating

Item	Symbol	Rating	Unit
Input voltage	V_{IN}	-0.3 to 6.0	V
ILIM voltage	V_{ILIM}	-0.3 to 6.0	V
Control voltage	V_{EN}	-0.3 to 6.0	V
Output voltage	V_{OUT}	-0.3 to V_{IN} + 0.3 or 6 which is smaller	V
Power dissipation	P_D	0.7 (Note 1)	W
Junction temperature	Tj	150	°C
Storage temperature	T_{stg}	-55 to 150	°C

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.
Board area: 76.2 mm × 114.3 mm (4-layer board), t = 1.6 mm

5. Operating Range

Table 5.1 Operating Range

Item	Symbol	Ranges		Unit
Input voltage	V_{IN}	1.7 to 5.5 (Note 2)		V
Output current	I_{OUT}	DC	0 to 1.0	A
		Pulse	0 to 2.0 (Note 3)	A
ILIM pin external resistor	R_{ILIM}	6.8 to 36		kΩ
Control voltage	V_{EN}	0 to 5.5		V
Operating junction temperature	Tj_opr	-40 to 125		°C

Note 2: Please be sure to also review Section 16, “Attention in Use”

Note 3: 500 μs pulse, duty ratio 2 %

6. Pin Assignments (Top view)

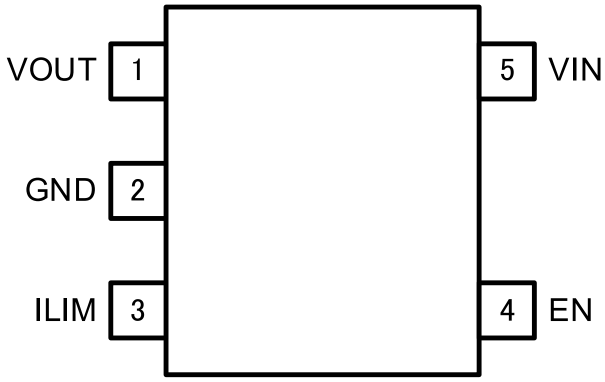


Fig 6.1 Pin Assignments

7. Top Marking (Top view)

Example: TCKE501UA

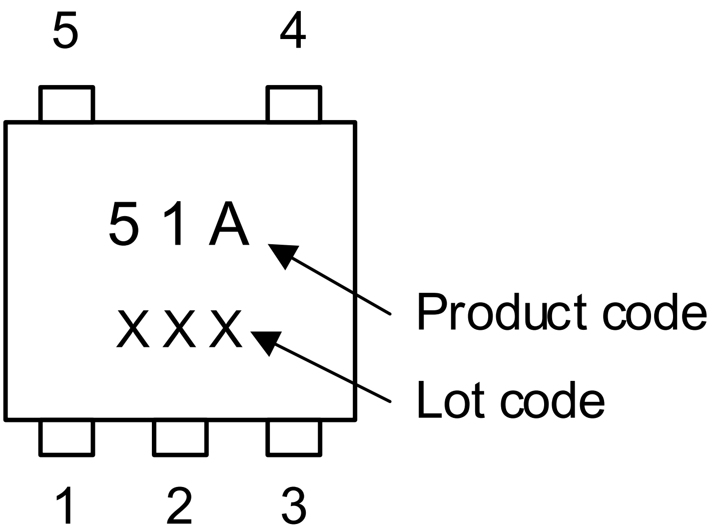


Fig 7.1 Marking

8. Product List

Table 8.1 Product List

Part number	V_{EN} Operation	Fault Response	Output Auto-dis-charge	V_{OUT} Rise time (V_{IN} = 5.0 V)	Top Marking
TCKE501UA	Active High	Auto-retry	Yes	800 μs	51A
TCKE502UA	Active High	Auto-retry	Yes	1450 μs	52A

9. Block Diagram

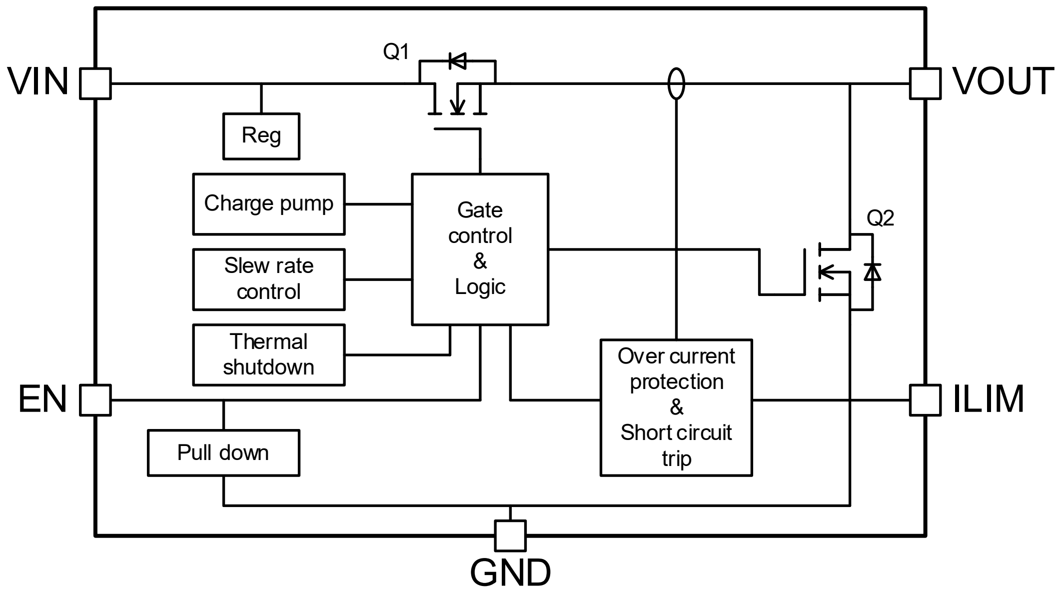


Fig 9.1 Block Diagram

10. Pin Description

Table 10.1 Pin Description

Pin No.	Pin Name	Description
1	VOUT	Output pin.
2	GND	GND pin.
3	ILIM	The ILIM pin is used to adjust the overcurrent detection threshold by connecting a resistor between the ILIM pin and the GND pin. Do not leave this pin open.
4	EN	Turns on the output voltage when used as an enable signal. Active high.
5	VIN	Input power supply pin.

11. Operation Logic Table

Conditions: 1.7 V ≤ V_{IN} ≤ 5.5 V, Ta = -40 to 125 ºC

Table 11.1 Operation Logic Table

	EN "Low"	EN " High"
Output (Q1)	OFF	ON
Discharge (Q2)	ON	OFF

12. Electrical Characteristics

Table 12.1 Electrical Characteristics

(Unless otherwise specified, V_{IN} = 3.3 V, R_{ILIM} = 13.3 kΩ, R_{LOAD} = 100 Ω, C_{IN} = C_{OUT} = 1 μF)

Characteristics	Symbol	Test condition	Ta = 25 °C			Ta = -40 to 125 °C (Note 4)		Unit
			Min	Typ.	Max	Min	Max	
Basic characteristics								
VIN undervoltage lockout (UVLO) Threshold voltage	V_{IN_UVLO}	Rising	–	1.3	–	0.7	1.6	V
VIN undervoltage lockout (UVLO) hysteresis (Note 6)	V_{IN_UVhyst}		–	70	–	–	–	mV
EN threshold voltage, rising	V_{ENR}		–	1.00	–	–	1.50	V
EN threshold voltage, falling	V_{ENF}		–	0.96	–	0.50	–	V
EN pull down resistance	R_{EN}	V_{EN} = 5.5 V	–	483	–	330	680	kΩ
On-resistance (Note 5)	R_{ON}	V_{IN} = 1.7 to 5.5 V, I_{OUT} = 1.0 A	–	75	100	–	135	mΩ
Quiescent current (ON Status)	I_Q	V_{IN} = 5.5 V, I_{OUT} = 0 A, V_{EN} = 3 V	–	132	–	–	200	μA
Quiescent current (OFF Status)	$I_{Q(OFF)}$	V_{IN} = 5.5 V, V_{EN} = 0 V	–	0.07	–	–	5.00	μA
Output Discharge resistance (Note 5)	R_{SD}	V_{IN} = 5.5 V, I_{OUT} = 0.1 A	–	1.0	–	–	2.0	Ω
		V_{IN} = 1.7 V, I_{OUT} = 0.1 A (Note 6)	–	3.0	–	–	–	Ω
Overcurrent Protection								
Overcurrent protection threshold (Note 5)	I_{OCP}	R_{ILIM} = 36 kΩ, Ta = 0 to 60 °C	–	0.20	–	0.15	0.25	A
		R_{ILIM} = 36 kΩ	–		–	0.14	0.26	
		R_{ILIM} = 13.3 kΩ, Ta = 0 to 60 °C	–	0.500	–	0.425	0.575	
		R_{ILIM} = 13.3 kΩ	–		–	0.415	0.585	
		R_{ILIM} = 6.8 kΩ, Ta = 0 to 60 °C	–	1.00	–	0.90	1.10	
		R_{ILIM} = 6.8 kΩ	–		–	0.88	1.12	
		R_{ILIM} = Short (Note 6)	–	1	–	–	–	
Overcurrent protection mask time (Note6)	t_{OCP}	I_{OUT} = 0 to 1.5 A	–	2.4	–	–	–	ms
Fast trip comparator level (Note 6)	I_{SHORT}		–	2.8	–	–	–	A
Short circuit response time (Note 6)	t_{SHORT}	I_{OUT} > I_{SHORT} → I_{OUT} = 0 A	–	1.3	–	–	–	μs
Thermal shutdown Protection								
Thermal shutdown Threshold (Note 6)	T_{SD}	Tj	–	150	–	–	–	°C
Thermal shutdown hysteresis (Note 6)	T_{SDH}	Tj (Auto-retry only)	–	20	–	–	–	°C
Auto-retry								
Auto-retry interval (Note 6)	t_{RST}	Auto-retry only	–	110	–	–	–	ms

Note 4: This parameter is warranted by design.

Note 5: Pulsed testing techniques used during this test maintain junction temperature approximately equal to ambient temperature.

Note 6: This parameter is reference only.

13. Switching Characteristics (Note 6)

(Unless otherwise specified, R_{ILIM} = 13.3 kΩ, R_{LOAD} = 100 Ω, C_{OUT} = 1 μF, Ta = 25 ° C)

Table 13.1 Switching Characteristics V_{IN} = 5.0 V

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Turn on delay	$t_{D,ON}$	TCKE501	–	1320	–	μs
		TCKE502	–	1750	–	μs
Turn off delay	$t_{D,OFF}$		–	6	–	μs
Turn on rise time	t_R	TCKE501	–	800	–	μs
		TCKE502	–	1450	–	μs
Turn off fall time	t_F		–	6	–	μs

Table 13.2 Switching Characteristics V_{IN} = 3.3 V

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Turn on delay	$t_{D,ON}$	TCKE501	–	1340	–	μs
		TCKE502	–	1760	–	μs
Turn off delay	$t_{D,OFF}$		–	6	–	μs
Turn on rise time	t_R	TCKE501	–	600	–	μs
		TCKE502	–	1150	–	μs
Turn off fall time	t_F		–	8	–	μs

Table 13.3 Switching Characteristics V_{IN} = 1.8 V

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Turn on delay	$t_{D,ON}$	TCKE501	–	1340	–	μs
		TCKE502	–	1730	–	μs
Turn off delay	$t_{D,OFF}$		–	8	–	μs
Turn on rise time	t_R	TCKE501	–	400	–	μs
		TCKE502	–	750	–	μs
Turn off fall time	t_F		–	14	–	μs

Note 6: This parameter is reference only.

13.1. Evaluation Circuit

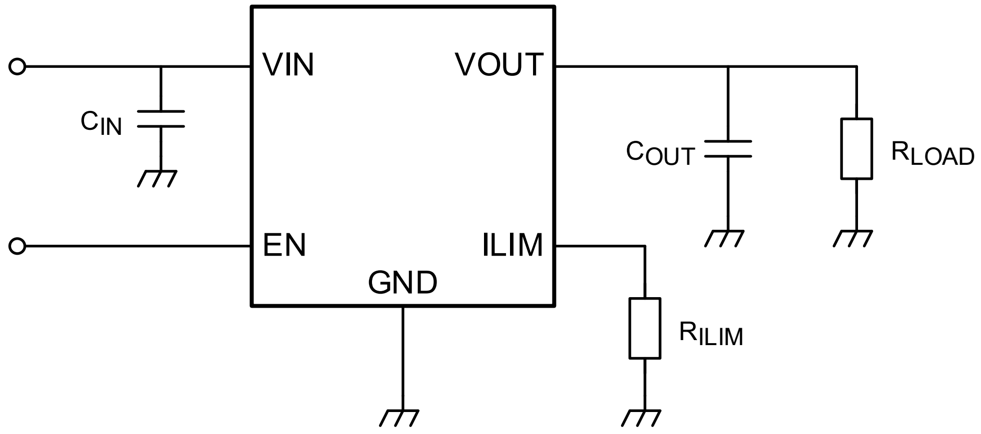


Fig 13.1 Evaluation Circuit

13.2. Switching Characteristics Waveform

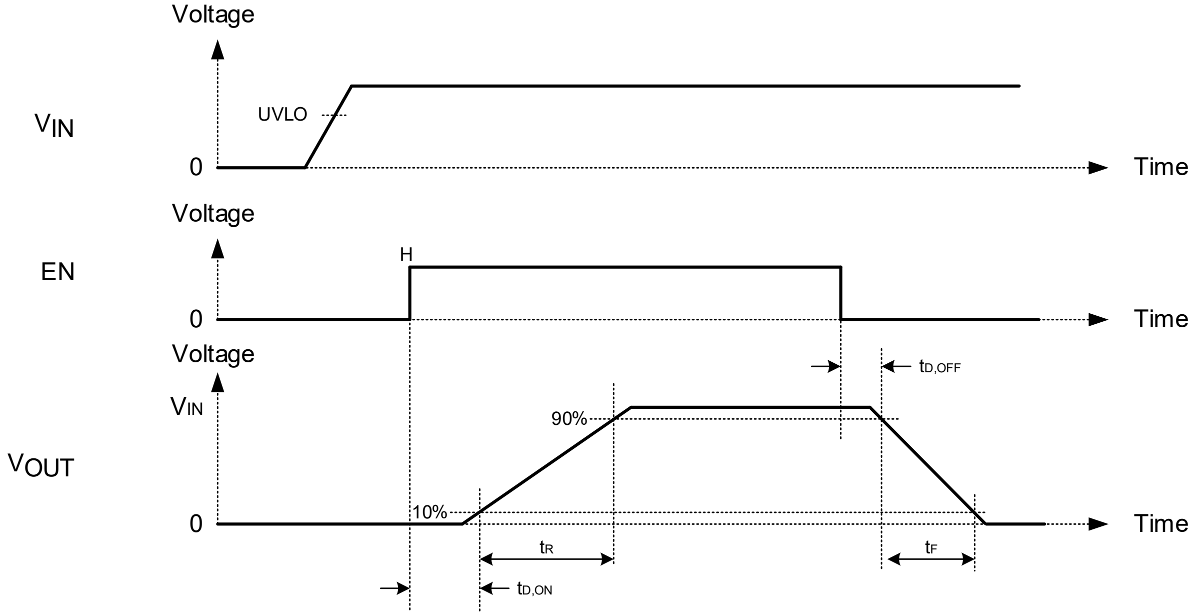


Fig 13.2 Switching Characteristics Waveform

14. Function Explanation

14.1. Overview

The TCKE5 series is an eFuse IC designed for safe power delivery within systems.
When the input voltage (V_{IN}) exceeds the undervoltage lockout (UVLO) threshold voltage (V_{IN_UVLO}), the IC enters standby mode. Once the enable voltage (V_{EN}) rises above the enable threshold voltage (V_{ENR}), the internal output MOSFET (Q1) turns on, allowing current to flow from VIN to VOUT. If the enable pin voltage drops below the disabled threshold voltage V_{ENF}, the internal output MOSFET (Q1) turns off.
This IC features an overcurrent protection function with an adjustable threshold, configured via an external resistor R_{ILIM}. When the current exceeds the detection threshold (I_{OCP}), the IC shuts down the output after a mask time (t_{OCP}). This function allows transient peak load current to pass without tripping protection. Additionally, the IC also provides short-circuit protection, enabling a rapid shutdown to overcurrent events that exceed the short-circuit protection threshold (I_{SHORT}).
This overcurrent and short-circuit protection provide a robust and reliable protection solution.

14.2. Slew Rate Control

When the output is turned on, it controls the V_{OUT} rise time (slew rate). This function suppresses the charging current (inrush current) of the C_{OUT} capacitor.
The TCKE5 series has a fixed slew rate control function and is available in two fixed slew rate options.

Table 14.1 Output Slew Rate Control Table

Test condition	TCKE501 (Typ.)	TCKE502 (Typ.)	Unit
V_{IN} = 1.8 V	400	750	μs
V_{IN} = 3.3 V	600	1150	μs
V_{IN} = 5.0 V	800	1450	μs

R_{ILIM} = 13.3 kΩ, R_{LOAD} = 100 Ω, C_{OUT} = 1 μF, Ta = 25 °C

14.3. VIN Under Voltage Lockout (VIN UVLO)

This function stops the operation of the eFuse IC when the V_{IN} is low, preventing malfunction of the load. The TCKE5 series starts operating when V_{IN} exceeds V_{IN_UVLO}. This voltage has hysteresis V_{IN_UVhyst} during both rising and falling edges.

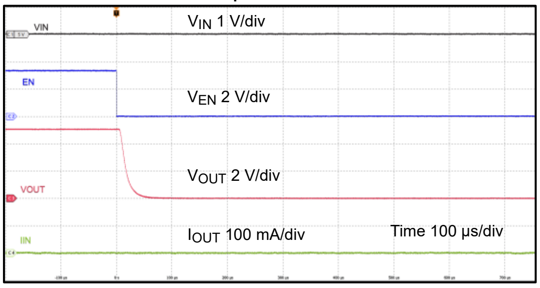
14.4. EN Pin

The TCKE5 series provides an EN pin to control the IC operation. The EN pin is pulled down to GND by an internal pull-down resistor R_{EN}; therefore, the IC remains OFF when EN pin is left open.
ON/OFF operation is controlled via the EN pin.

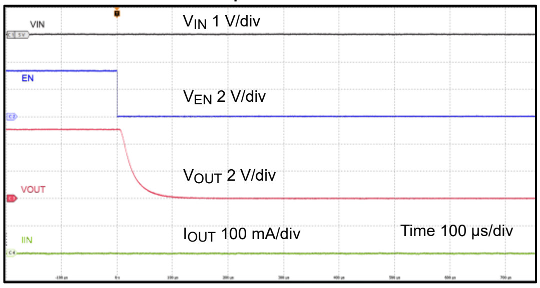
14.5. Output Auto-Discharge

When the VEN falls below VENF and the IC turns OFF, the discharge MOSFET between the VOUT pin and the GND pin discharges the external capacitor C_{OUT}. The discharge MOSFET operates in the saturation region with constant-current discharge. After entering the linear region, it discharges resistively.
The figure below shows the discharge waveforms. The discharge time of the output voltage is determined by the output capacitor and the load resistance.

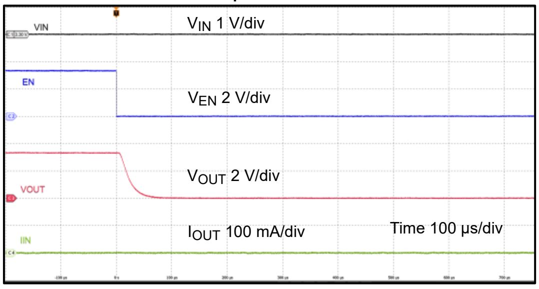
V_{IN} = 5 V, EN = H → L, C_{OUT} = 10 μF,
R_{LOAD} = Open, Ta = 25 °C



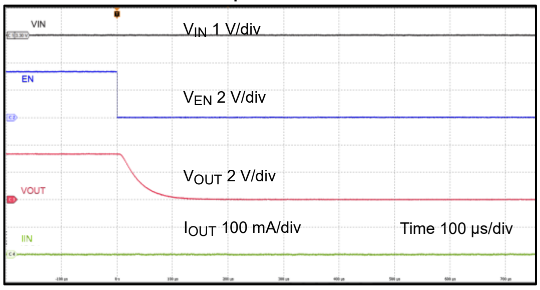
V_{IN} = 5 V, EN = H → L, C_{OUT} = 22 μF,
R_{LOAD} = Open, Ta = 25 °C



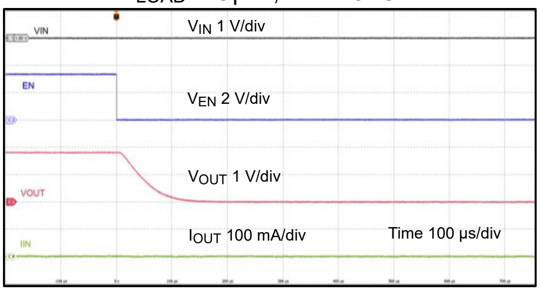
V_{IN} = 3.3 V, EN = H → L, C_{OUT} = 10 μF,
R_{LOAD} = Open, Ta = 25 °C



V_{IN} = 3.3 V, EN = H → L, C_{OUT} = 22 μF,
R_{LOAD} = Open, Ta = 25 °C



V_{IN} = 1.8 V, EN = H → L, C_{OUT} = 10 μF,
R_{LOAD} = Open, Ta = 25 °C



V_{IN} = 1.8 V, EN = H → L, C_{OUT} = 22 μF,
R_{LOAD} = Open, Ta = 25 °C

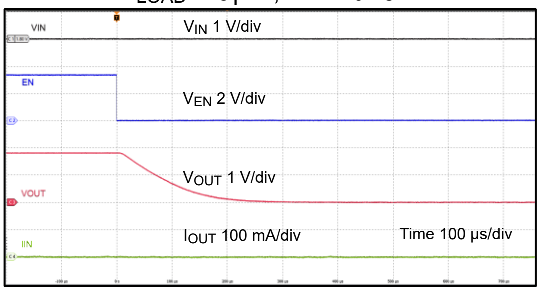


Fig 14.1 Output Auto-Discharge Waveforms

14.6. VOUT Short Circuit Protection (Fast trip)

The short-circuit protection function (Fast trip) prevents excessive current when a short circuit occurs in the power supply line or load. In the TCKE5 series, a short-circuit condition is detected when the output current exceeds the short-circuit protection threshold (I_{SHORT}).

14.6.1. Auto-Retry Type VOUT Short Circuit Protection

When the output current exceeds I_{SHORT} due to a VOUT short circuit, the IC turns off the output. After the auto-retry interval (t_{RST}), the IC restarts. If the VOUT short-circuit condition persists, the output current again exceeds I_{SHORT}, and the output is turned off.

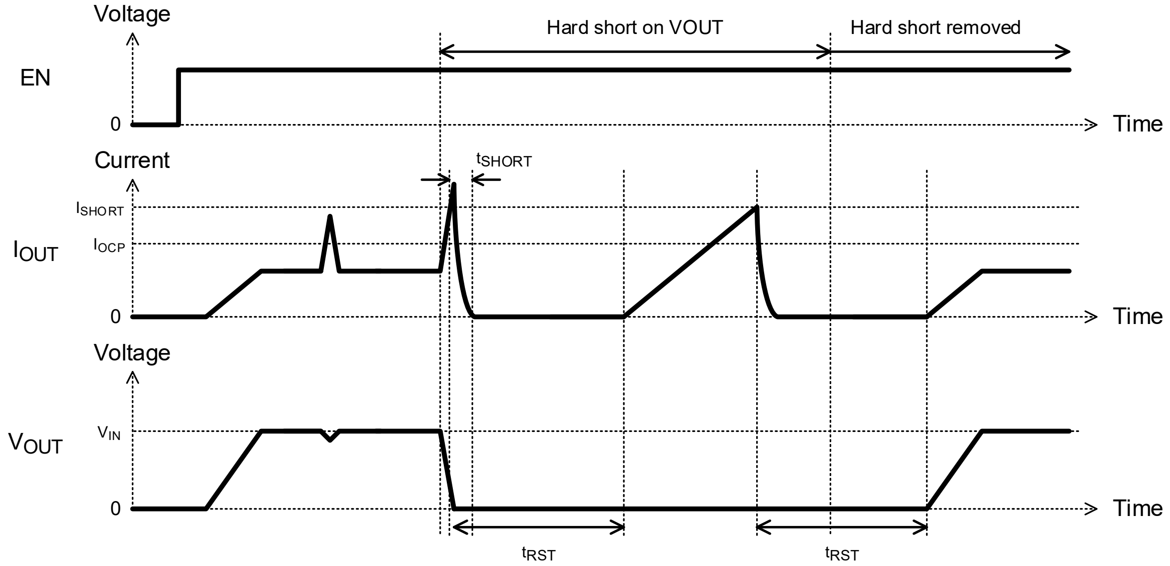


Fig 14.2 Auto-Retry Timing Chart for VOUT Short Circuit Protection

Note: For the I_{SHORT} and I_{OCP} threshold levels immediately after IC startup, please refer to Section 14.8.

14.7. Overcurrent Protection (OCP)

The overcurrent protection prevents excessive current when an abnormal load condition causes the output current to exceed the set threshold I_{OCP}. In TCKE5 series, OCP is activated when the output current exceeds the I_{OCP} (and remains below I_{SHORT}) for longer than the mask time (t_{OCP}).

14.7.1. Setting the Overcurrent Protection

The limit current can be set to the optimal value for the application by selecting an external resistor R_{ILIM} connected to the ILIM pin. The I_{LIM} calculation formula is common to the TCKE5 series and is shown below. Since this formula is theoretical, the resistance value should be verified using the actual device when selecting the R_{ILIM}.

$$R_{ILIM}\ (k\Omega) = \frac{6.69}{I_{OCP}\ (A) - 0.007}$$

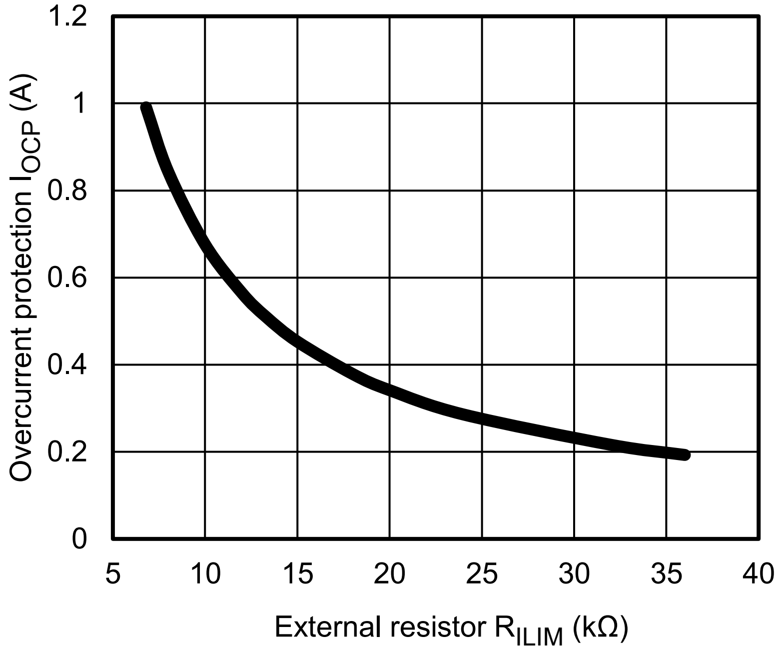


Fig 14.3 Overcurrent Protection Threshold I_{OCP} vs External resistor R_{ILIM}

The table below shows the reference characteristics between the overcurrent detection threshold (I_{OCP}) and the external resistor R_{ILIM}. These characteristics are provided as design guidelines based on the I_{OCP} calculation formula; actual characteristics should be verified in the target device and application circuit.

Table 14.2 Overcurrent protection threshold I_{OCP} vs External resistor R_{ILIM} (Example)

I_{OCP} (A)	R_{ILIM} Theoretical value (kΩ)	R_{ILIM} Closest standard value (kΩ)
1.0	6.74	6.81
0.8	8.44	8.25
0.6	11.3	11.5
0.4	17.0	16.9
0.2	34.7	34.8

When the ILIM pin is left open, the I_{OCP} is set to nearly 0 A.

14.7.2. ILIM pin short circuit protection

When the ILIM pin is shorted to GND, the internal IOCP is set to 1 A (Typ.).

14.7.3. Auto-Retry Type Overcurrent Protection

When the output current reaches I_{OCP} and a time longer than the t_{OCP} has elapsed after the overcurrent is detected, the IC turns off the output. After the t_{RST}, operation starts again. At this time, if the overcurrent condition has not been resolved, the output current reaches I_{OCP} again. After a time longer than the t_{OCP}, the output is turned off again.

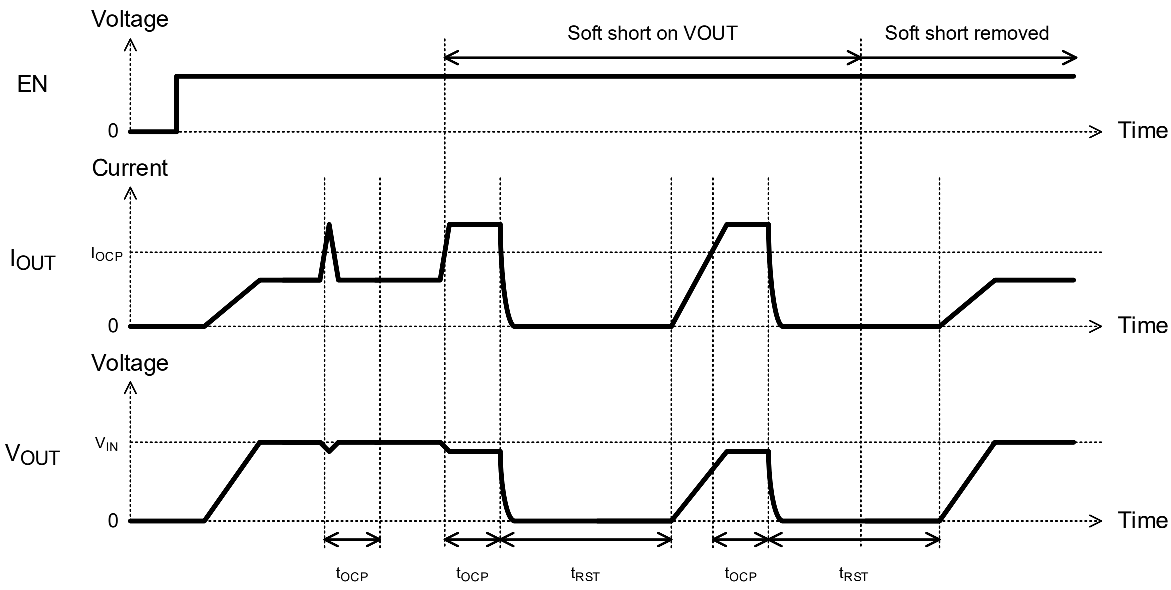


Fig 14.4 Auto-Retry Timing Chart for Overcurrent Protection

Note: For the I_{SHORT} and I_{OCP} threshold levels immediately after IC startup, please refer to Section 14.8.

14.8. Fast Trip and OCP at eFuse IC Startup

The I_{SHORT} and I_{OCP} values defined in Section 12. "Electrical Characteristics" apply in the stable operating region (in the figure below), which is reached approximately 14 ms or more after EN transitions from "L" to "H."
Immediately after IC startup, the protection thresholds are as shown in the table below. Please take this into consideration when using the device.

Table 14.3 Fast Trip and OCP Threshold at eFuse IC Startup

Region	I_{SHORT} / I_{OCP}
1	Approximately the same as in region 3
2	Approximately 2 to 3 times the values defined in Section 12, Electrical Characteristics
3	Defined in Section 12, Electrical Characteristics

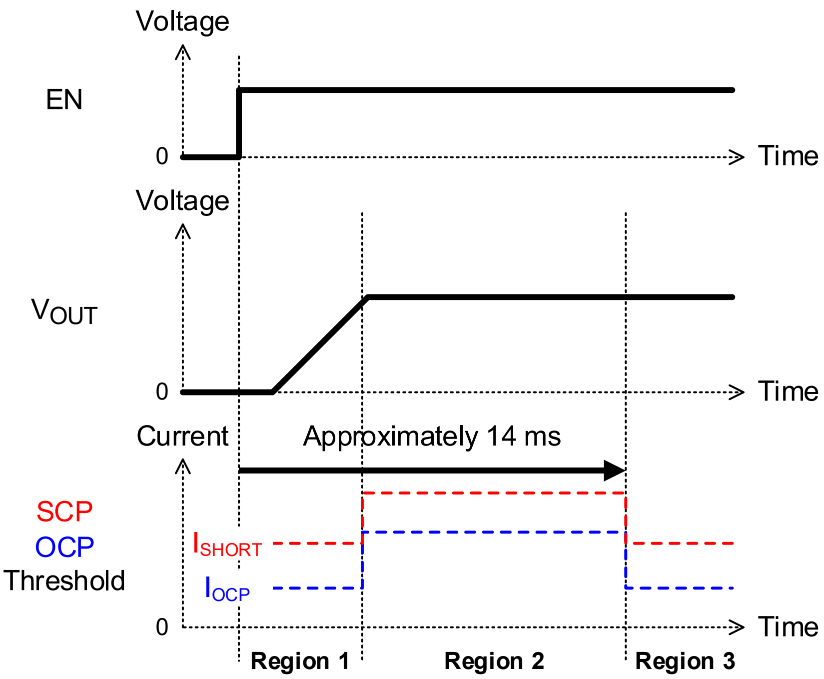


Fig 14.5 eFuse IC Startup Timing Chart for Fast Trip and OCP

14.9. Thermal Shutdown Protection

The overheat protection (thermal shutdown) is a function that turns off the IC when the junction temperature of IC exceeds the set point (T_{SD}). In TCKE5 series, auto-retry type for the auto-recovery and the latch type for external manipulation are lined up as the recovery methods from the overheat protection operation to normal operation.

In the auto-retry type, the IC has hysteresis (T_{SDH}) temperature between detect temperature and return temperature. After the IC is turned off due to overheat protection, the unit restarts after the t_{RST}.

In the latch type, the IC is turned off due to overheat protection. To recover from the problem, the EN pin must be restarted by applying a control signal again. The protection operation continues until it is restarted.

14.9.1. Auto-Retry Type Thermal Shutdown

The IC turns off V_{OUT} if the junction-temperature exceeds T_{SD}. After the output is turned off due to overheat protection, the equipment is restarted after the t_{RST}. At this time, if the junction temperature continues to exceed the set value, the output is turned off again.

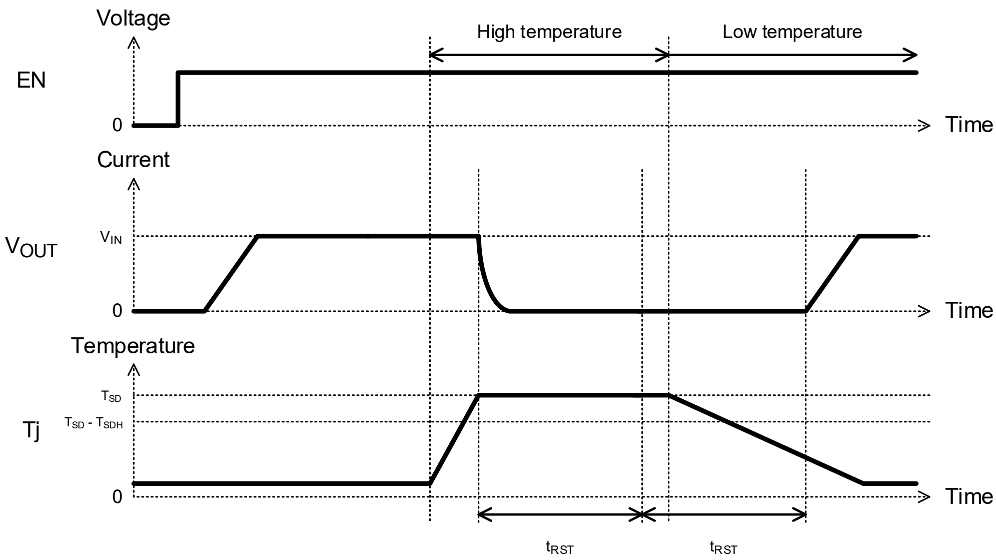


Fig 14.6 Auto-Retry Timing Chart for Thermal Shutdown

14.10. State Transition Diagram

Q1 : Output MOSFET
Q2 : Discharge MOSFET

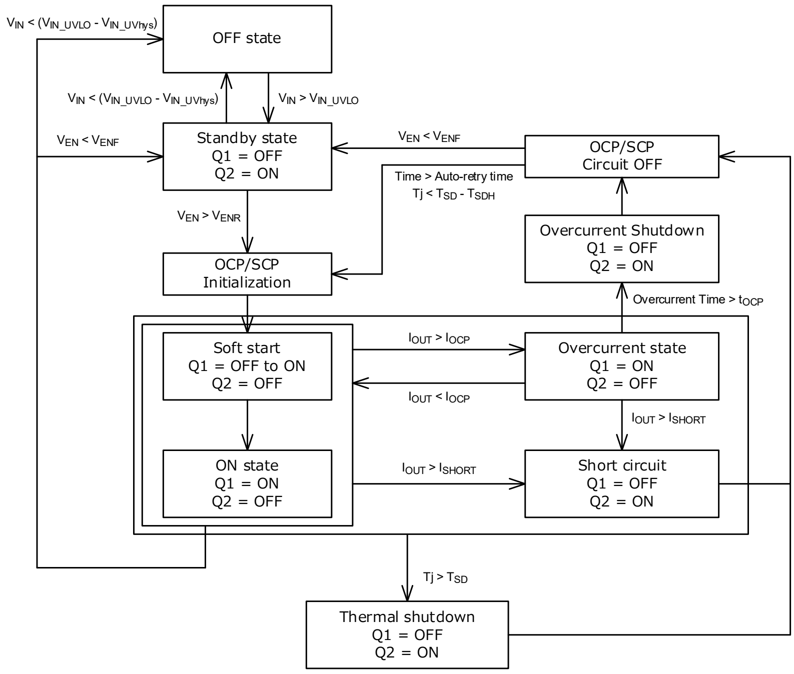


Fig 14.7 State Transition Diagram

Note: For the I_{SHORT} and I_{OCP} threshold levels immediately after IC startup, please refer to Section 14.8.

15. Application Note

15.1. Application Circuit Example

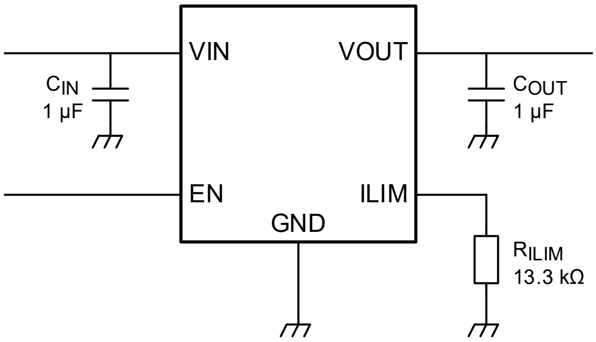


Fig 15.1 Application Circuit Example for TCKE5 series

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 protection is activated, 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 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 C_{IN}.

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

V_{IN} : The power supply voltage during normal operation (V)

I_{OUT} : The output current (A)

L_{IN} : The effective inductance component of the input pin (H)

C_{IN} : The effective capacitance component of the input pin (F)

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 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.
Alternatively, increasing C_{OUT} can reduce negative spike voltages. When V_{IN} exceeds 5 V, it is recommended to increase C_{OUT} and install an SBD. Please always verify the behavior on the actual system.
As noted above, TVS diode or 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.

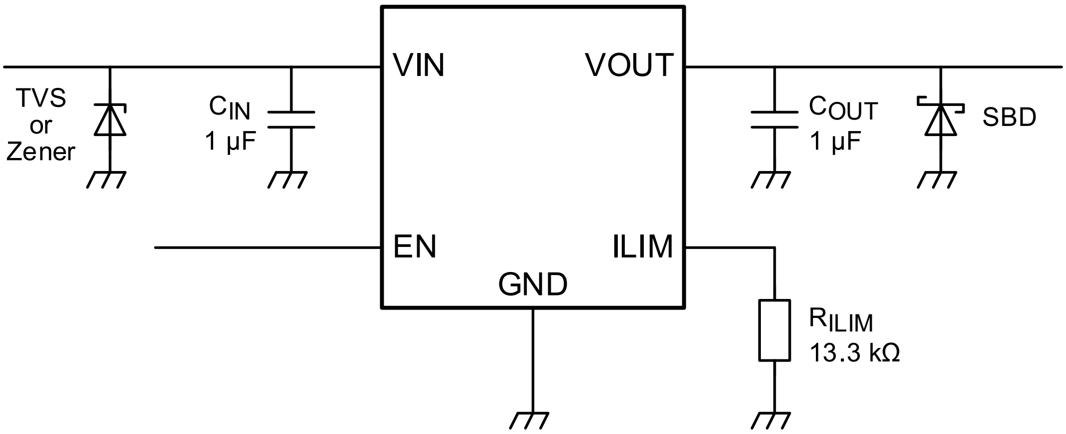


Fig 15.2 Application Circuit Example with External Protection Components

15.2. Power Dissipation

Power dissipation ratings for TCKE5 series are available on 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

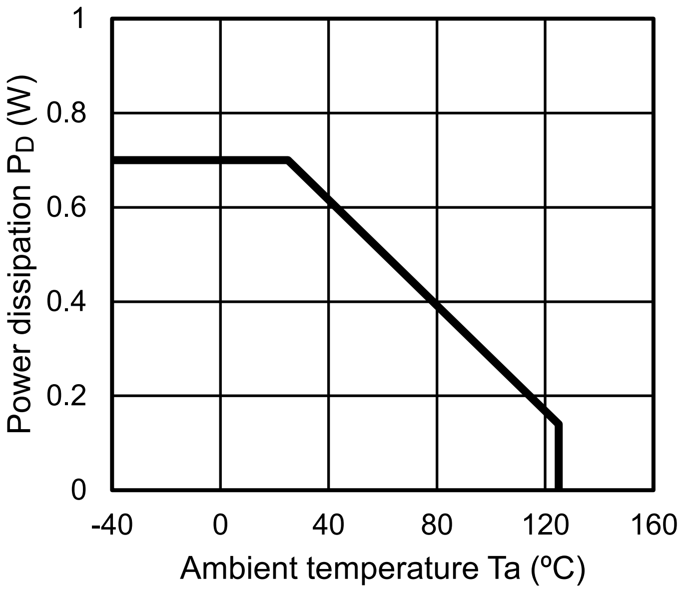


Fig 15.3 Power Dissipation

16. Attention in Use

- Input/Output capacitor
  Ceramic capacitors can be used with the IC; however, some types of capacitors may have very large temperature dependence. Please consider the usage environmental condition carefully when selecting the capacitors.
  If the output capacitor is large, the IC's protection functions may operate depending on the application conditions. Please always confirm the behavior on the actual system.

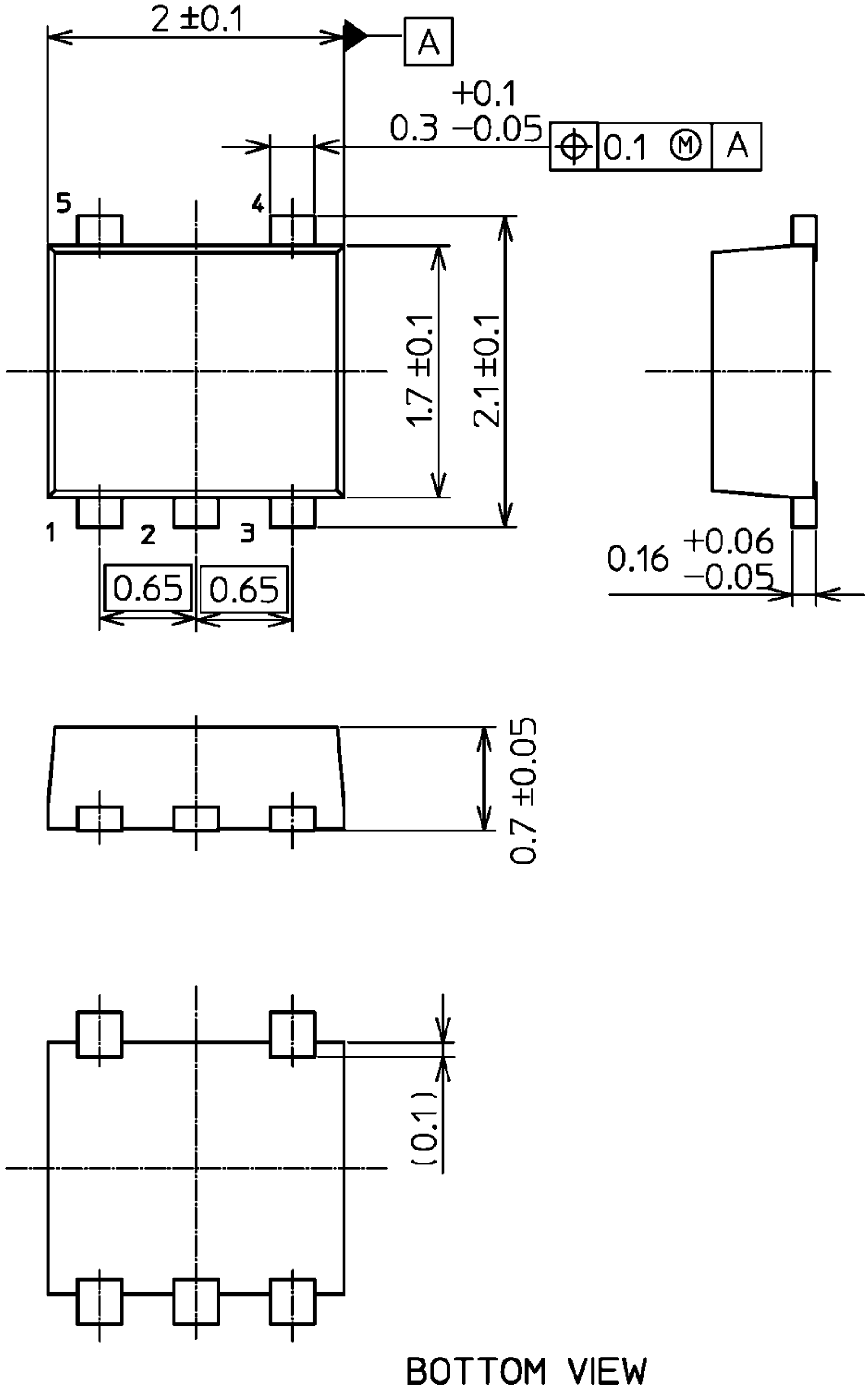
- Mounting
  The long distance between IC and output capacitors might affect stability due to trace impedance and parasitic inductance. For stable power supply, place the output capacitor as close to the IC as possible. Also, VIN and GND patterns need to be large and make the wire impedance small as possible.

- Power Dissipation
  Please allow sufficient margin when designing a board pattern to fit the expected power dissipation. Also take into consideration the ambient temperature, input voltage, output current etc. and applying the appropriate derating for allowable power dissipation during operation.

- Protection circuit
  Overcurrent protection and Thermal shutdown 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 pins and GND pins are not completely shorted out, these products might break down.
  When using these products, please read through and understand the concept of dissipation for absolute maximum ratings from the abovementioned 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.
  Especially in the event of VOUT short circuit, the device absolute maximum ratings may be exceeded due to the impedance of the wiring. When V_{IN} is 5 V or higher, please implement appropriate countermeasures, such as connecting a C_{OUT} of 10 μF or greater (for example, Murata GRM155R60J106ME44) or connecting a SBD. Be sure to verify the operation on the actual system before use.

17. Package Information

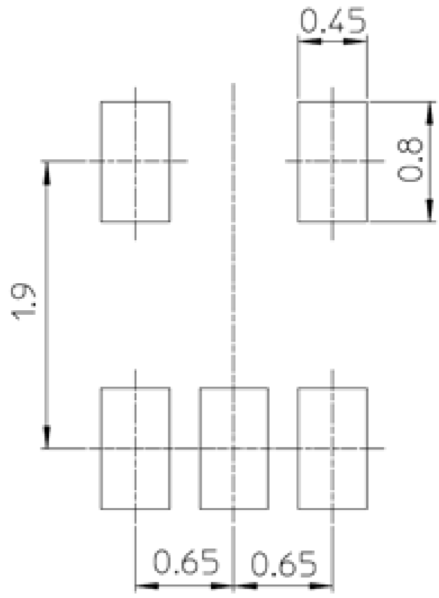
UFV (SOT-353F) Unit: mm



Weight: 7.2 mg (Typ.)

18. Land Pattern Dimensions (for reference only)

Unit: mm



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