Thermoflagger™ (Over temperature detection IC) TCTH0 series Application Note

Description

Toshiba Thermoflagger™ Over-Temperature Detection ICs offer a new approach to detecting and protecting against abnormal heat generation. Thermoflagger™ is designed to be connected in series with PTC Thermistors placed near heat sources.

This IC works by monitoring the resistance over the connected PTC thermistors, which increases exponentially when over temperature is observed. As a result, Thermoflagger™ will change output states and can be read by external systems which can then take appropriate actions.

This document outlines the basic behavior, detailed operation, and precautions of Thermoflagger™.

Note: Thermoflagger™ is a trademark of Toshiba Electronic Devices & Storage Corporation.

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1. Introduction

For electronic equipment to perform as specified, their semiconductors and electronic components must operate within design parameters and temperature is one crucial parameter. If internal temperature becomes higher than what was expected during the design process, this is a major safety and reliability issue. Therefore, an overheat monitoring solution that detects over temperature is need.

This document explains the functions and operations of Thermoflagger™ (Over Temperature Detection ICs) when used with PTC thermistors as an overheating protection solution. Refer to the datasheet for product details.

2. What is Thermoflagger™?

A Thermoflagger™ is an IC that can detect a rise in the temperature of electronic equipment when combined with a PTC thermistor. This solution is simple and easy to make. The resistance of PTC thermistors is almost constant near room temperature. However, the resistance rises rapidly when the temperature rises above the detected temperature, and it is used to protect against overheating. Thermoflagger™ detects changes in the resistance value of a PTC thermistor and inverts FLAG signal when a PTC thermistor is overheated. Thermoflagger™ adopts a circuit to detect resistive changes by supplying a low constant current to a connected PTC thermistor. In addition, several PTC thermistors can be connected in series. As a result, it is possible to detect the temperature at any location in the electronic circuit. If you want to change the detected trigger temperature in each location, you can easily do so by changing the PTC thermistor.

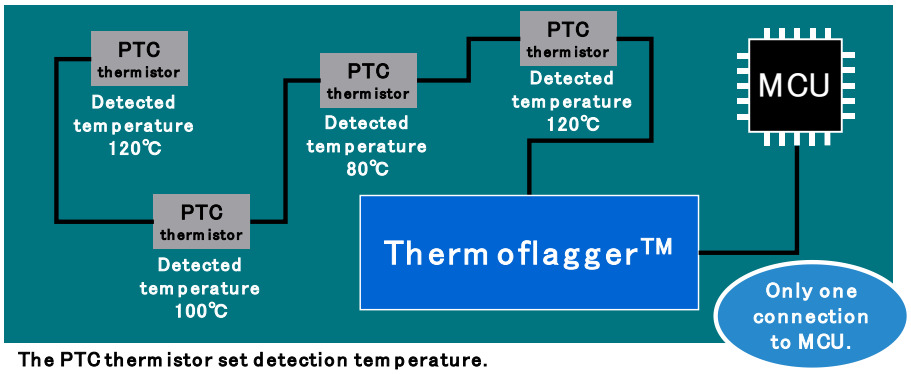

Figure 2-1 Over temperature protection solution with Thermoflagger™ with PTC thermistor

3. Block diagram and circuit description of TCTH0 series

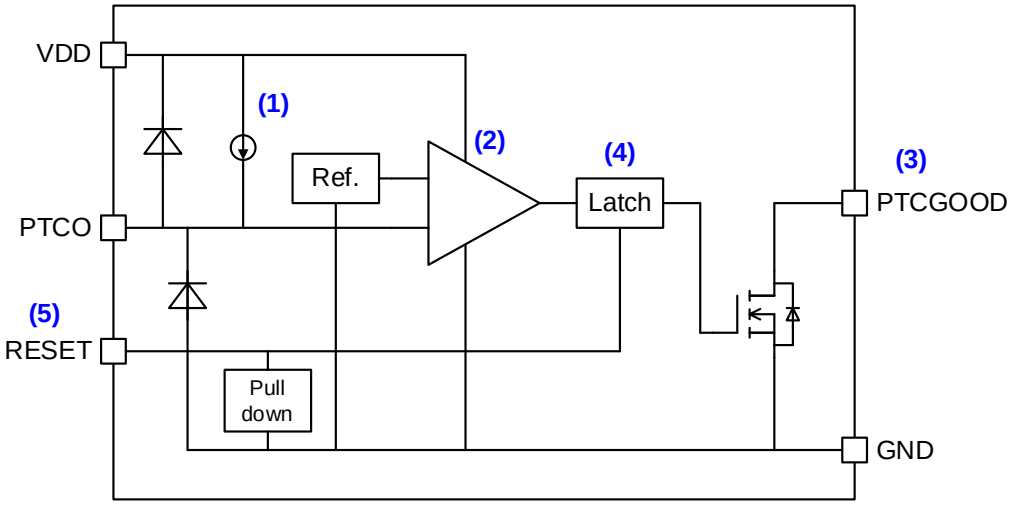

Figure 3-1 Block diagram of TCTH0 series

(1) Constant current source (PTCO output current)

Constant current is supplied from the PTCO terminal and converted to voltage by using the resistor of a connected PTC thermistor. When the PTC thermistor has a large resistance, PTCO voltage (V_{PTCO}) increases to the supply voltage (V_{DD}). V_{PTCO} also rises to V_{DD} when PTCO terminal is open. Constant current values differ for each product. Refer to the product data sheet for details.

Table 3-1 PTCO output current of TCTH0 series

Characteristics	Symbol	Test Condition	T_j = 25 °C			T_j = -40 to 125 °C		Unit
			Min	Typ.	Max	Min	Max	
PTCO output current	I_{PTCO}	TCTH01xxE, V_{DD} = 3.3 V	0.92	1.00	1.08	0.76	1.27	μA
		TCTH01xxE, V_{DD} = 1.7 V to 5.5 V	0.80	1.00	1.22	0.72	1.32	μA
		TCTH02xxE, V_{DD} = 3.3 V	9.2	10.0	10.8	7.6	12.7	μA
		TCTH02xxE, V_{DD} = 1.7 V to 5.5 V	8.0	10.0	12.2	7.2	13.2	μA

(2) Internal comparator

When V_{PTCO} exceeds the detection voltage (V_{DET}), the output of the internal comparator is inverted and "Low" is output from the PTCGOOD terminal.

Table 3-2 Internal comparator threshold of TCTH0 series

Characteristics	Symbol	Test Condition	T_j = 25 °C			T_j = -40 to 125 °C		Unit
			Min	Typ.	Max	Min	Max	
Detect Voltage	V_{DET}	V_{DD} = 3.3 V	0.42	0.50	0.58	0.36	0.64	V
Hysteresis voltage	V_{DETHYS}	V_{DD} = 3.3 V, TCTH0x1xE※	−	0.1	—	—	—	V

Note: The non-FLAG latch function type (TCTH0x1xE) has a hysteresis (V_{DETHYS}) in its comparator.

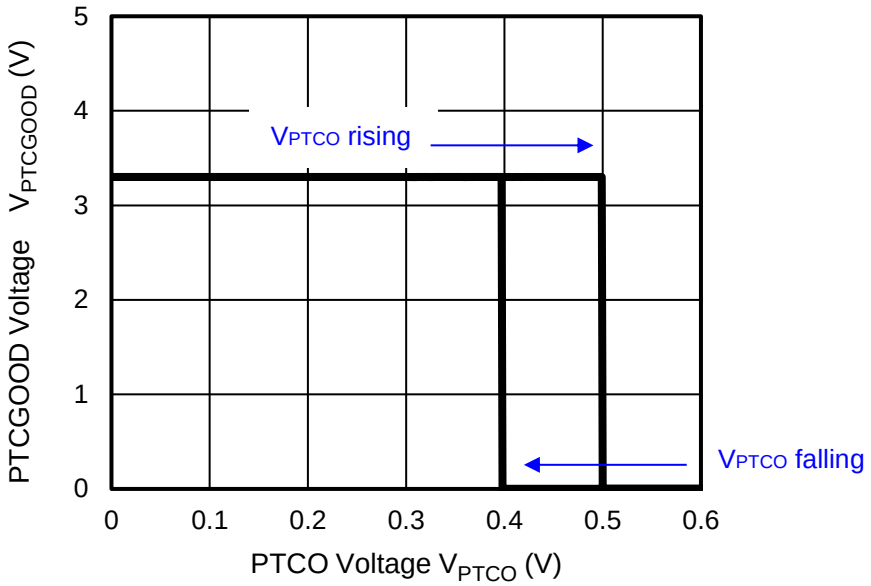

Figure 3-2 Detect Voltage (V_{DET}) of TCTH0x1xE

(3) FLAG signal output (PTCGOOD)

FLAG is output from PTCGOOD terminal when the measured V_{PTCO} exceeds V_{DET}. There are two types of FLAG terminals: open-drain type and push-pull type. The open-drain type requires pull-up resistor. In contrast, the Push-pull type requires neither a pull-up nor a pull-down resistor. FLAG function differs for each product. Refer to the product data sheet for details.

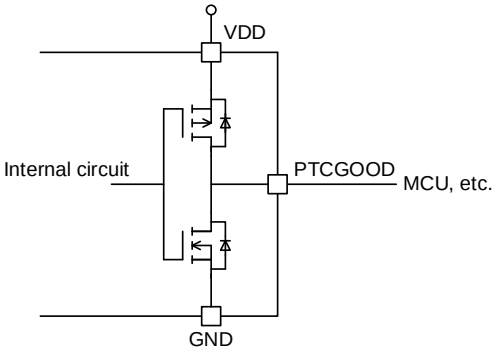

Figure 3-3 PTCGOOD block diagram of push-pull type (TCTH0xxAE)

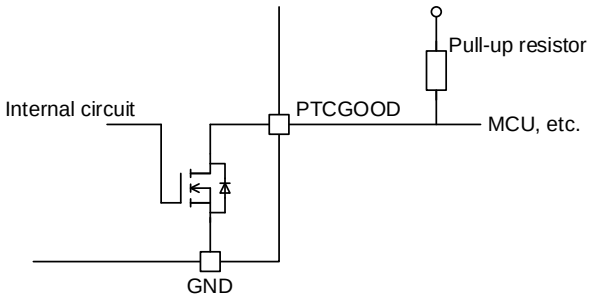

Figure 3-4 PTCGOOD block diagram of open-drain type (TCTH0xxBE)

Table 3-3 TCTH0 series lineup table (Output type)

Product name	Output type
TCTH0xxAE	Push-pull
TCTH0xxBE	Open-drain

Table 3-4 PTCGOOD output voltage

Characteristics	Symbol	Test Condition	T_j = 25 °C			T_j = -40 to 125 °C		Unit
			Min	Typ.	Max	Min	Max	
PTCGOOD High level output voltage	V_{OH}	TCTH0xxAE, $I_{PTCGOOD}$ = -4 mA, V_{DD} = 3.3 V	3.03	—	—	—	—	V
PTCGOOD Low level output voltage	V_{OL}	$I_{PTCGOOD}$ = 4 mA, V_{DD} = 3.3 V	—	—	0.2	—	—	V

(4) FLAG signal latch function

After the FLAG signal is inverted, the FLAG signal is latched, even in the event that the temperature drops at the PTC thermistor, which results in V_{PTCO} dropping as well. The latch is released by applying a signal to the RESET pin. Options are available with a built-in FLAG signal latch function. Refer to the product datasheet for details.

Table 3-5 TCTH0 series lineup table (FLAG signal latch function)

Product name	FLAG signal latch function
TCTH0x1xE	None
TCTH0x2xE	Yes

(5) RESET pin

To release the FLAG signal latch function, apply a voltage to the RESET pin.

The terminal is pulled down between RESET pin and GND by using a Depletion type Nch MOSFET. This MOSFET maintains the current flowing at a constant rate even when the voltage is increased. Do not apply more than V_{DD} to RESET terminal.

Table 3-6 RESET input voltage, Pull-down current

Characteristics	Symbol	Test Condition	T_j = 25 °C			T_j = -40 to 125 °C		Unit
			Min	Typ.	Max	Min	Max	
Threshold of RESET pin High level	$V_{IHRESET}$		0.84	—	V_{DD}	1.00	V_{DD}	V
Pull-down current at RESET pin	I_{RESET}		—	0.04	—	—	—	μA

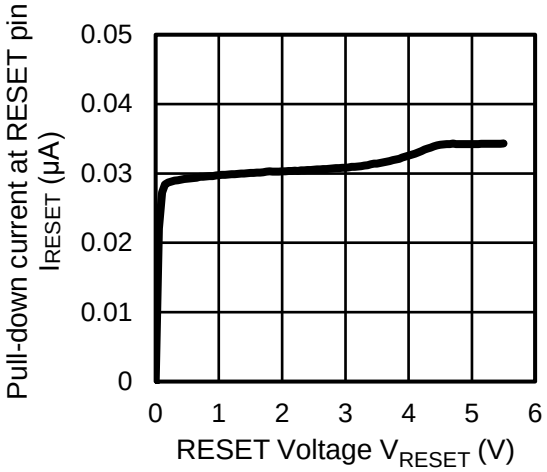

Figure 3-5 Pull-down current at RESET pin

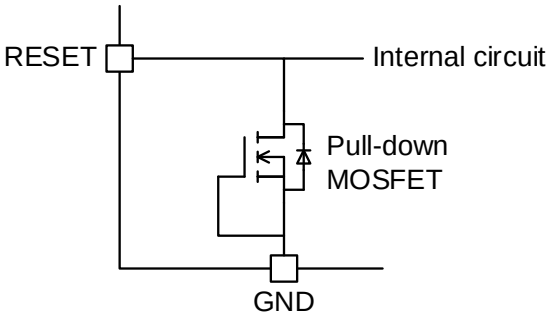

Figure 3-6 RESET pin circuit

4. Thermoflagger™ operation example

This IC outputs a FLAG signal when PTC thermistor exceeds a threshold temperature. Detailed operation is as follows.

4.1. TCTH0x1xE (without FLAG signal latch function)

This section explains the operation of TCTH021BE. Figure 4-1 shows the circuit diagram, and Figure 4-2 shows the operating waveform.

① When PTC thermistor is at room temperature, FLAG signal outputs "High".
② If PTC thermistor exceeds a threshold level, FLAG signal outputs "Low".
③ When PTC thermistor is at room temperature again, FLAG signal outputs "High" again.

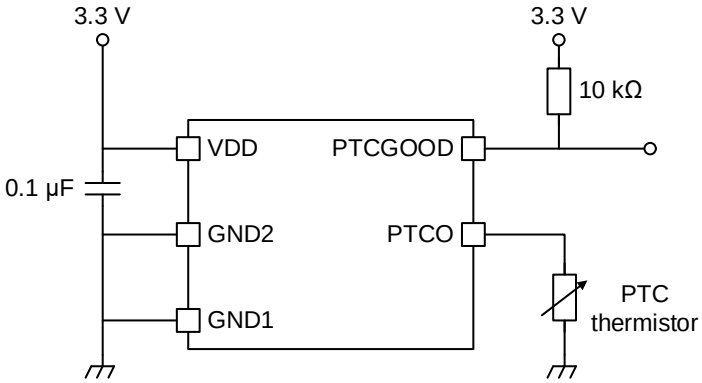

Figure 4-1 TCTH021BE circuit diagram

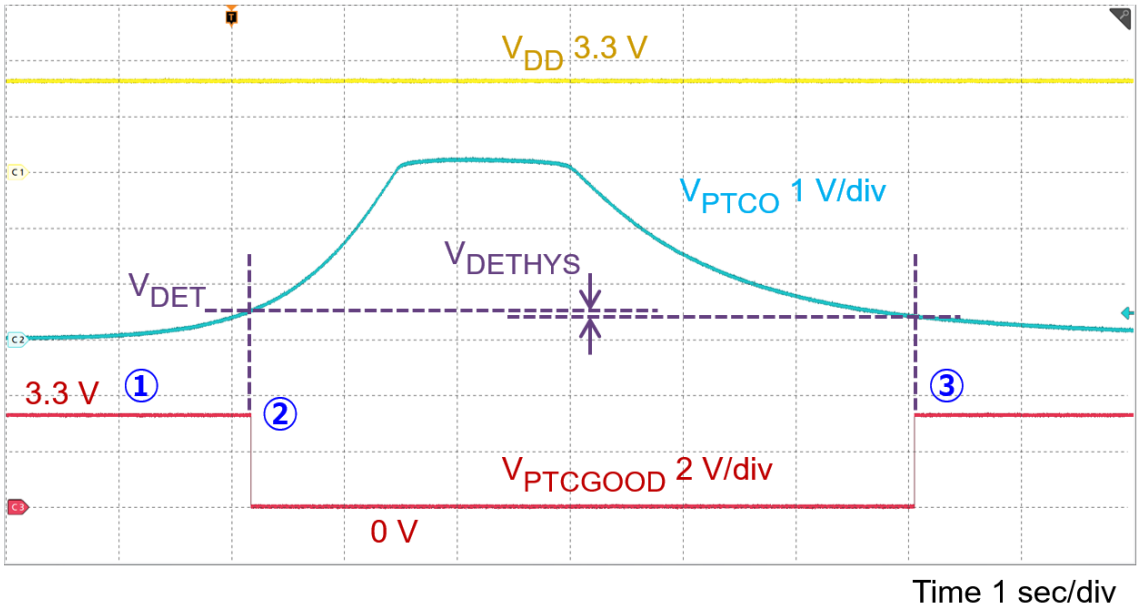

Figure 4-2 Operating waveform of TCTH021BE

4.2. TCTH0x2xE (with FLAG signal latch function)

This section explains the operation of TCTH022BE. Figure 4-3 shows the circuit diagram, and Figure 4-4 shows the operating waveform.

① When PTC thermistor is at room temperature, FLAG signal outputs "High".
② When PTC thermistor exceeds a threshold temperature. FLAG signal outputs "Low".
③ Even when PTC thermistor reapplies to normal temperature, FLAG signal remains "Low". FLAG signal outputs "High" by applying voltage to RESET terminal.

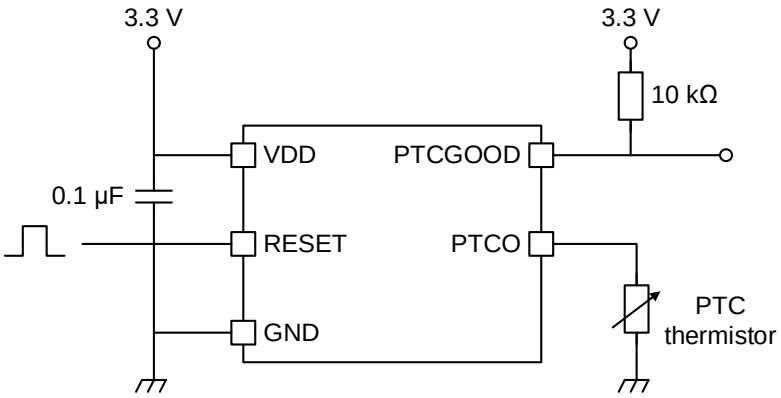

Figure 4-3 TCTH022BE circuit diagram

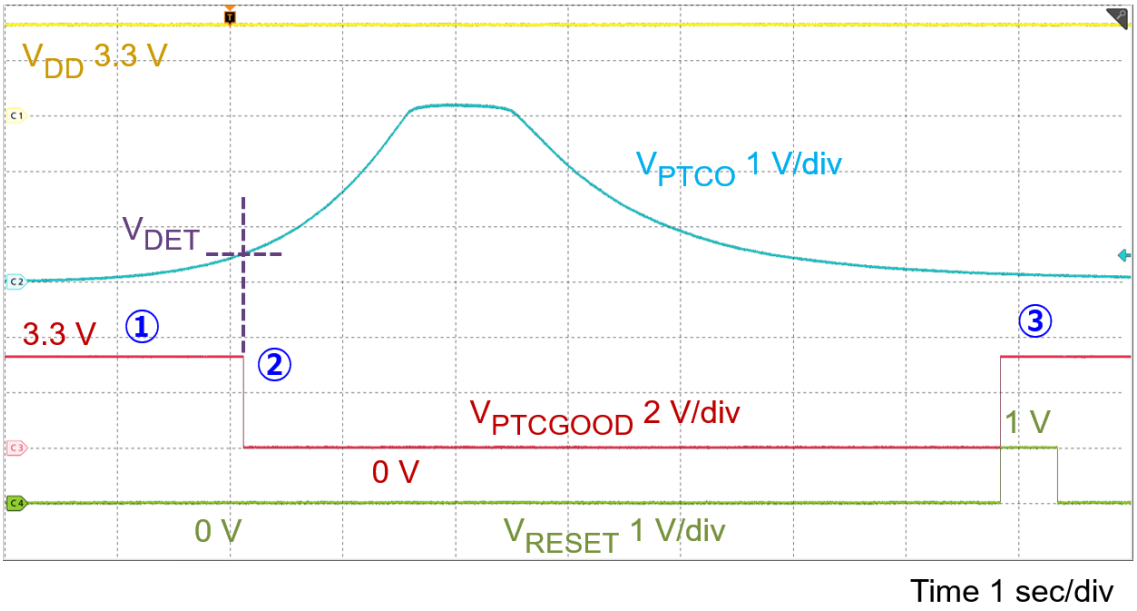

Figure 4-4 Operating waveform of TCTH022BE

5. How to select a PTC thermistor

The resistor value of PTC thermistors increases when the temperature exceeds the threshold. PTCO voltage (V_{PTCO}) generates with PTC thermistor characteristics and PTCO output current. PTCGOOD outputs “Low” when PTC PTCO voltage is higher than the detect voltage (V_{DET}).

There are 2 different PTCO output currents to select from. It’s important to select a PTC thermistor that matches each PTCO output current. Refer to the following.

5.1. Usage with signal PTC thermistor

Refer to the following to select a PTC thermistor for IC detecting when resistance of PTC thermistor becomes α times the one on normal conditions.

$$\frac{V_{DET}\ (Max.)}{I_{PTCO}\ (Min.) \times \alpha} < \text{PTC thermistor resistance at normal operation} < \frac{V_{DET}\ (Min.)}{I_{PTCO}\ (Max.) \times \beta}$$

α: The rate of changing PTC thermistor resistance $\left(\alpha = \frac{\text{resistance at over temperature operation}}{\text{resistance at normal operation}}\right)$

β: V_{DET} margin coefficient, Set with guideline as $10 \leq \beta \leq \alpha/4$

Note: Design for PTC thermistor resistance variation and margins.

Table 5-1 Reference PTC thermistor resistance for single pc.

Product name	PTCO output current (Typ.)	PTC thermistor resistance (25 °C)	
		α = 50, β = 10	α = 100, β = 10
TCTH01xxE	1 μA	17.8 kΩ to 27 kΩ	9.1 kΩ to 27 kΩ
TCTH02xxE	10 μA	1.78 kΩ to 2.7 kΩ	910 Ω to 2.7 kΩ

5.2. Using several (N pcs) PTC thermistors

When using several PTC thermistors, select the thermistors with same resistance value at 25 °C. if using different thermistors in same system, the IC may not correctly detect when over temperature occurs.

Maximum number of PTC thermistors can be connected is around 30 pcs.

Ex.) Refer to the next formula to select the PTC thermistors, in order to detect when the resistor value changed to α times when one of the PTC thermistors is overheated, using N pcs of PTC thermistors have same resistor value at 25 °C.

$$\frac{V_{DET}\ (Max.)}{I_{PTCO}\ (Min.) \times (\alpha + N - 1)} < \text{PTC thermistor resistance at normal operation} < \frac{V_{DET}\ (Min.)}{I_{PTCO}\ (Max.) \times \beta \times N}$$

N: PTC thermistor quantity

α: The rate of changing PTC thermistor resistance $\left(\alpha = \frac{\text{resistance at over temperature operation}}{\text{resistance at normal operation}}\right)$

Set α to be at least (4 + N/2) × β or more, as guideline.

β: V_{DET} margin coefficient, set β to be N + 10 as guideline.

Note: Design for PTC thermistor resistance variation and margins.

If in a condition that multiple PTC thermistors are to be overheated at the same time, the combined resistance after overheating should be considered when setting the system in order to avoid a false positive of the IC. Refer to the table below for more details.

Table 5-2 Reference PTC thermistor resistance using several (N) pcs.

Product name	PTCO output current (Typ.)	PTC thermistor resistance (25 °C)	
		N = 10, α = 180, β = 20	N = 10, α = 300, β = 20 (When α is increased)
TCTH01xxE	1 μA	4.7 kΩ to 9.4 kΩ	2.8 kΩ to 9.4 kΩ
TCTH02xxE	10 μA	470 Ω to 940 Ω	280 Ω to 940 Ω

6. Thermoflagger™ Applications

The following are application examples.

Thermal protection solutions using Thermoflagger™, and PTC thermistors are suitable around power supply circuitry in consumer and industrial equipment. Place PTC thermistors near MOSFETs or other heat sources.

(1) Notebook PC, etc.

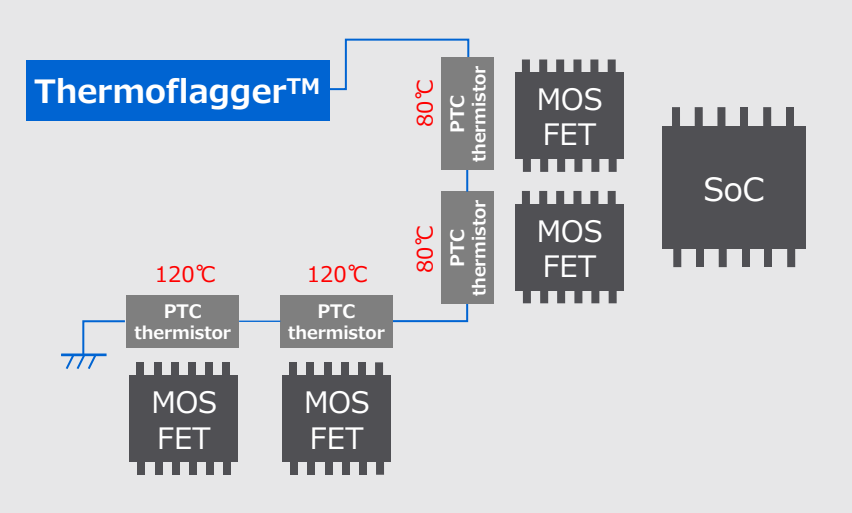

Figure 6-1 Notebook PC Application example

(2) Hand drills, Robotic vacuum cleaners, Printers, etc.

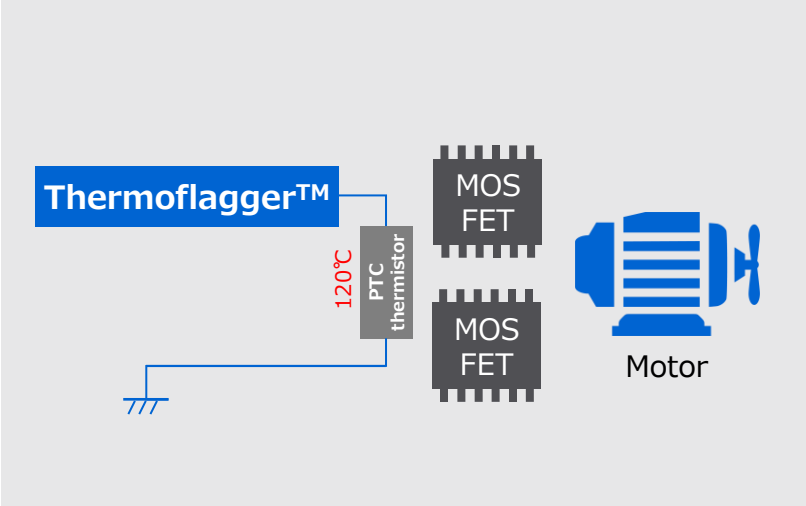

Figure 6-2 Hand drills, Robotic vacuum cleaner, and Printers Application example

7. Notes on Contents

7.1. Capacitor for power supply terminal

For stable Thermoflagger™ operation, connect a capacitor between VDD and GND as close to the IC.

7.2. GND pin

All GND pins must be connected to the system GND.

7.3. PTCO pin

Do not apply a voltage exceeding 1 V from outside.

7.4. Design Considerations

If the system is noisy, the internal comparator of the IC may detect incorrectly. Before using the product, design it with sufficient consideration.

7.5. Precautions for layout

We recommend designing the board so that PTC thermistor and Thermoflagger™ are sufficiently far from each other to prevent heat generation from being transmitted to Thermoflagger™.

7.6. Others

When using this device, please read through and understand the concepts described and follow absolute maximum ratings from the information datasheet or from our ‘Semiconductor Reliability Handbook’. Please operate these products below absolute maximum ratings in all instances. Furthermore, Toshiba highly recommends inserting failsafe systems into the design.

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