

Linux Interface Specification Device Driver Thermal Sensor

User's Manual: Software

RZ/G2L Group, RZ/V2L Group, RZ/V2N Group,
RZ/G3E Group and RZ/Five

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1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).

7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

How to Use This Manual

1. Purpose and Target Readers

This manual is designed to provide the user with an understanding of the hardware functions and electrical characteristics of the MPU. It is intended for users designing application systems incorporating the MPU.. It is intended for users developing software incorporating the processors. A basic knowledge of software development and Linux systems is necessary in order to use this document.

Particular attention should be paid to the precautionary notes when using the manual. These notes occur within the body of the text, at the end of each section, and in the Usage Notes section.

The revision history summarizes the locations of revisions and additions. It does not list all revisions. Refer to the text of the manual for details.

The following documents apply to the RZ/G2L Group, RZ/V2L Group, RZ/Five Group, RZ/G3E Group and RZ/V2N Group. Make sure to refer to the latest versions of these documents. The newest versions of the documents listed may be obtained from the Renesas Electronics Web site.

Document Type	Description	Document Title	Document No.
User's manual for Hardware	Hardware specifications (pin assignments, memory maps, peripheral function specifications, electrical characteristics, timing charts) and operation description Note: Refer to the application notes for details on using peripheral functions.	RZ/G2L Group User's Manual: Hardware	---
		RZ/V2L Group User's Manual: Hardware	---
		RZ/Five Group User's Manual: Hardware	---
		RZ/V2N Group User's Manual: Hardware	---
		RZ/VG3E Group User's Manual: Hardware	---
User's manual for Software	Description of Thermal Linux interface Specification	Linux interface Specification Device Driver Thermal Sensor	This User's manual
Application Note	Information on using peripheral functions and application examples Sample programs Information on writing programs in assembly language and C	Available from Renesas Electronics Web site.	
Renesas Technical Update	Product specifications, updates on documents, etc.		

2. Notation of Numbers and Symbols

3. Register Notation

4. List of Abbreviations and Acronyms

Abbreviation	Full Form
TSU	<u>T</u> hermal <u>S</u> ensor <u>U</u> nit.
TSC	<u>T</u> hermal <u>S</u> ensor <u>C</u> ontroller.
Thermal zone	Represents a region managed by thermal framework.

Table of Contents

1. Overview.....	1
1.1 Overview	1
1.2 Function	1
1.3 Reference	2
1.3.1 Standard.....	2
1.3.2 Related documents	2
1.4 Restrictions	2
2. Terminology.....	3
3. Operating Environment.....	4
3.1 Hardware Environment	4
3.2 Software Configuration	5
4. External Interface.....	8
4.1 Sysfs Interface	8
4.2 Change Thermal Threshold	8
4.3 Setting for Interrupt or Polling Mode	11
5. Integration.....	14
5.1 Directory Configuration	14
5.2 Integration Procedure	14
5.3 Option Setting	15
5.3.1 Module Parameters	15
5.3.2 Kernel Parameters	15
5.4 Temperature calculation	15
5.4.1 Calculation for RZ/G2L Group, RZ/V2L and RZ/Five	15
5.4.2 Calculation for RZ/V2N and RZ/G3E	17

1. Overview

1.1 Overview

This manual explains the driver module (this module) that controls the Thermal Sensor Module on RZ/G2L Group, RZ/V2L Group, RZ/V2N Group, RZ/G3E Group and RZ/Five.

Note: Currently, the devices that support this function are RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L RZ/Five, RZ/V2N, and RZ/G3E.

It supports two kernel versions v5.10 and v6.1 as shown below:

- v5.10: RZ/G2L Group, RZ/V2L group and RZ/Five.
- v6.1: RZ/G2L, RZ/G2LC, RZ/V2N and RZ/G3E.

1.2 Function

This module monitors the temperature from the Thermal Sensor Controller with the following functions:

(1) Get current temperature of SoC by accessing sysfs. The accuracy is about:

- RZ/G2L Group, RZ/V2L and RZ/Five: $\pm 3^{\circ}\text{C}$
- RZ/G3E and RZ/V2N: $\pm 5^{\circ}\text{C}$

(2) Halt the system when SoC temperature exceeds predefined threshold. Regarding how to change the threshold, please refer to section 4.2.

(3) This temperature sensor contains an internal probe and a 12 bits A/D converter. It has a resolution of 0.0625°C and operates within junction temperature range of $-40\sim 125^{\circ}\text{C}$.

1.3 Reference

1.3.1 Standard

There is no reference document on standards.

1.3.2 Related documents

There is no document related to this kernel.

1.4 Restrictions

None.

2. Terminology

The following table shows the terminology related to this kernel.

Table 2-1 Terminology

Terms	Explanation
TSU	<u>T</u> hermal <u>S</u> ensor <u>U</u> nit.
TSC	<u>T</u> hermal <u>S</u> ensor <u>C</u> ontroller.
Thermal zone	Represents a region managed by thermal framework.

3. Operating Environment

3.1 Hardware Environment

The following table shows the hardware needed to use this kernel.

Table 3-1 Hardware environment for G2L series,RZ/Five

Name	Version	Manufacturer
RZ/G2L Evaluation Board Kit	SMARC module: v01 Carrier board: v03	Renesas Electronics Europe GmbH
RZ/G2LC Evaluation Board Kit	SMARC module: v01 Carrier board: v03	Renesas Electronics Europe GmbH
RZ/G2UL Evaluation Board Kit	SMARC module: v01 Carrier board: v03	Renesas Electronics Europe GmbH
RZ/V2L Evaluation Board Kit	SMARC module: v01 Carrier board: v03	Renesas Electronics Europe GmbH
RZ/Five Evaluation Board Kit	SMARC module: v01 Carrier board: v03	Renesas Electronics Europe GmbH

Table 3-2 Hardware environment for RZ/V2N and RZ/G3E

Name	Product number
RZ/V2N Evaluation Kit	RTK0EF0186C03000BJ
RZ/G3E SMARC Evaluation Board Kit	RTK9947E57S01000BE

3.2 Software Configuration

The following figures show the configuration of this module.

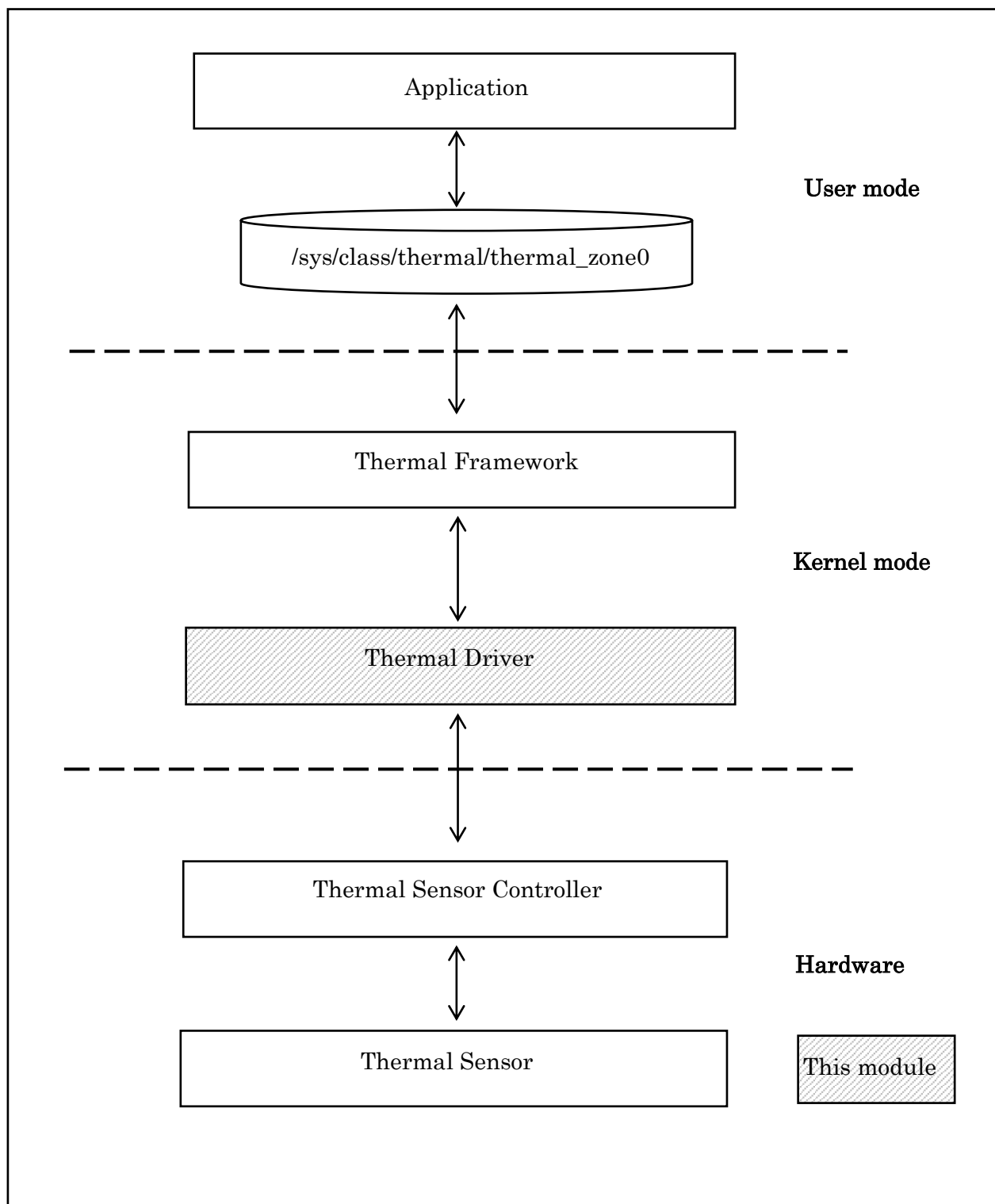


Figure 3-1 Module Configuration of RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five, RZ/G3E Group

The following figure shows the software flowchart of this module.

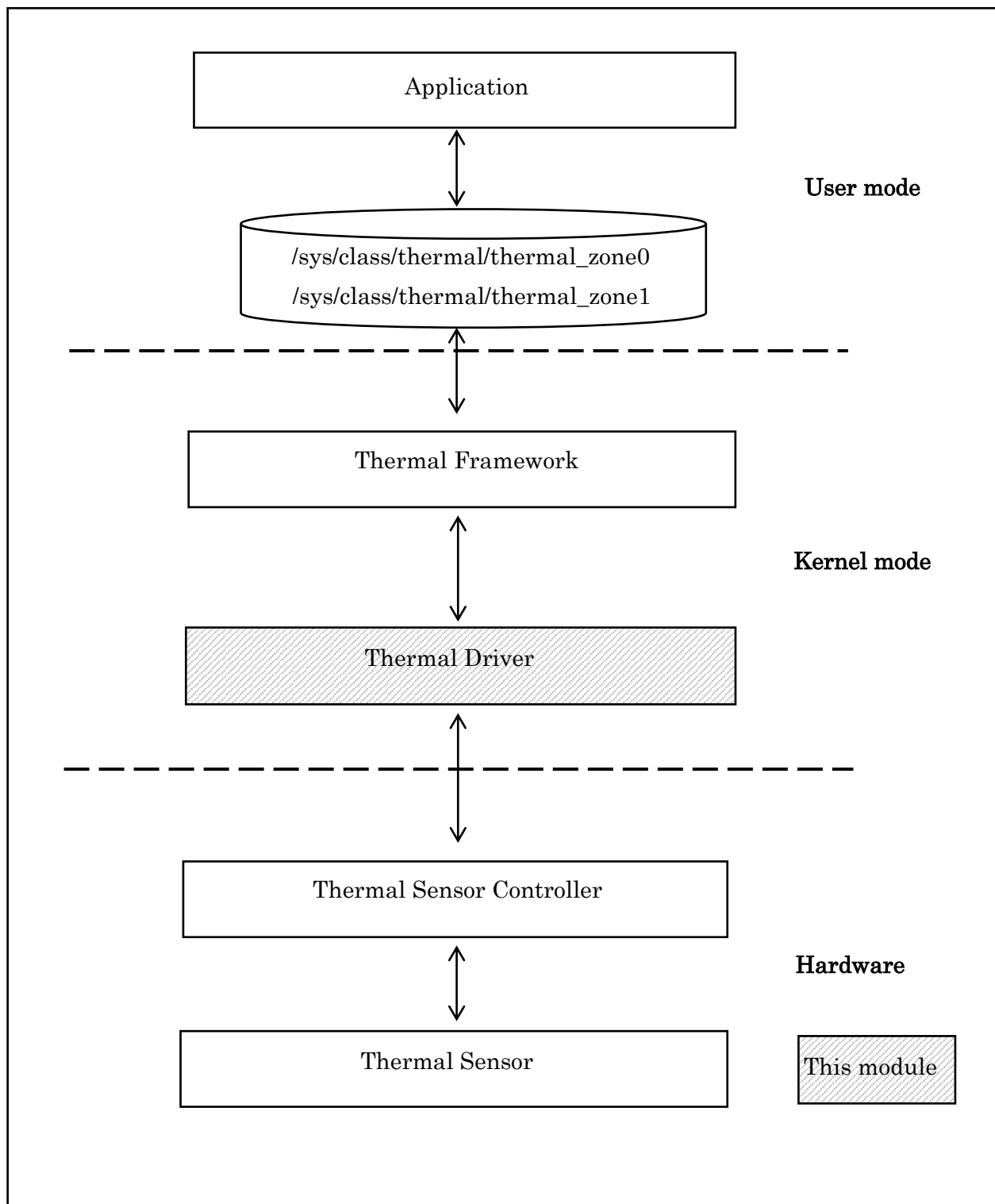
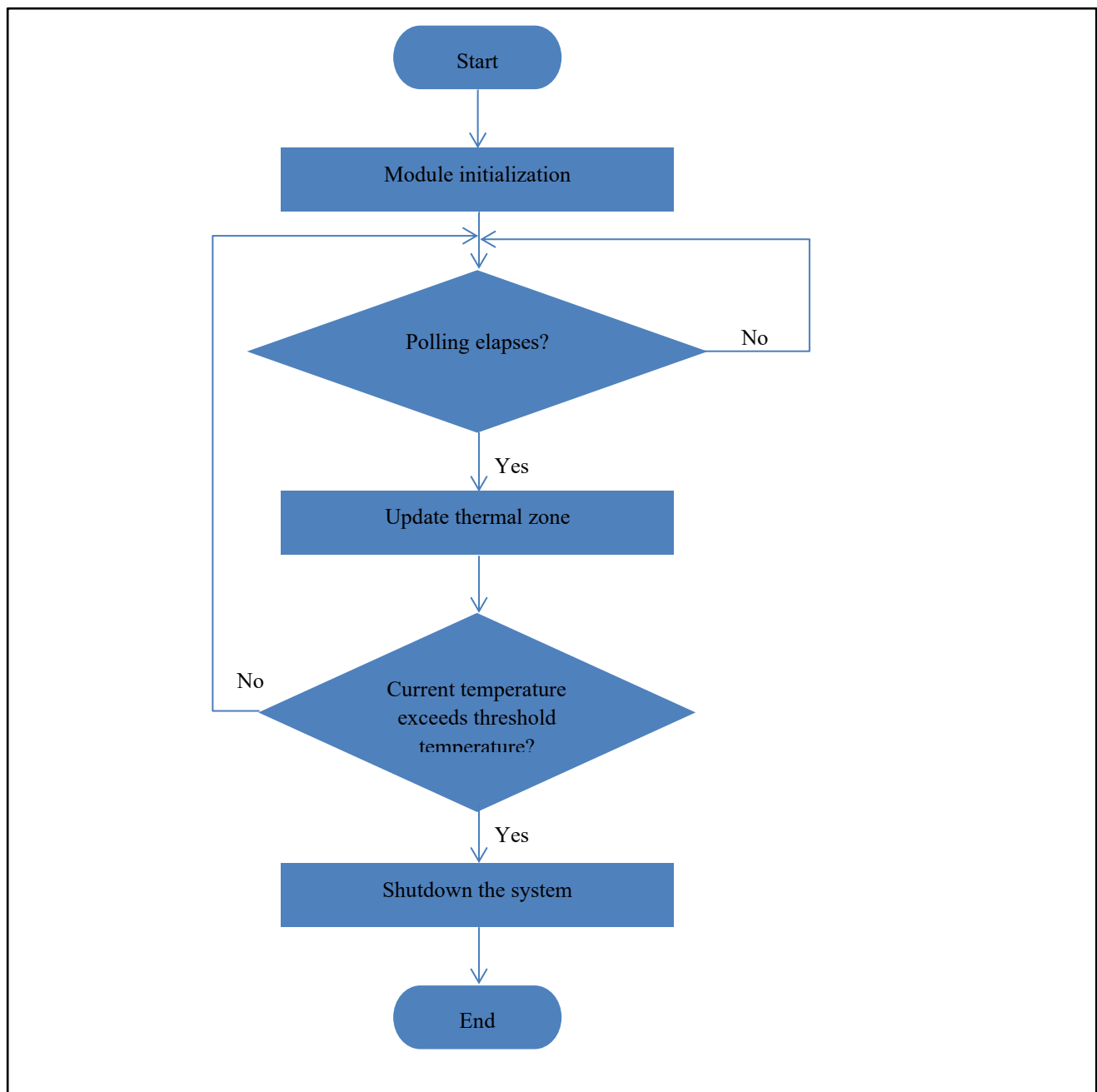


Figure 3-2 Module Configuration of RZ/V2N Group

**Figure 3-3 Thermal Sensor Software Flowchart**

4. External Interface

4.1 Sysfs Interface

Thermal driver does not provide directly external interface for user application. Instead, with thermal user interface, application can get current temperature of this SoC and trip point information as described in the table below.

Table 4-1 System information of thermal sensor driver (RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five, RZ/G3E Group)

Thermal Zone Interfaces	Notes
/sys/class/thermal/thermal_zone0/temp	Current temperature of this SoC (millicelsius)
/sys/class/thermal/thermal_zone0/trip_point_Y_type	Trip point type
/sys/class/thermal/thermal_zone0/trip_point_Y_temp	Trip point temperature

Table 4-2 System information of thermal sensor driver (RZ/V2N Group)

Thermal Zone Interfaces	Notes
/sys/class/thermal/thermal_zone0/temp	Current temperature of this SoC (millicelsius)
/sys/class/thermal/thermal_zone0/trip_point_Y_type	Trip point type
/sys/class/thermal/thermal_zone0/trip_point_Y_temp	Trip point temperature
/sys/class/thermal/thermal_zone1/temp	Current temperature of this SoC (millicelsius)
/sys/class/thermal/thermal_zone1/trip_point_Y_type	Trip point type
/sys/class/thermal/thermal_zone1/trip_point_Y_temp	Trip point temperature

4.2 Change Thermal Threshold

Thermal framework will halt the system when SoC temperature exceeds predefined threshold. Please modify device tree to define desired threshold temperature of corresponding thermal zone. Otherwise, it will be set to default value of 110000 (millicelsius) for RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five Group and 120000 (millicelsius) for RZ/V2N Group, RZ/G3E Group.

```
thermal-zones {
    sensor_thermal: sensor-thermal {
        polling-delay-passive = <250>;
        polling-delay = <1000>;
        sustainable-power = <3874>;
        thermal-sensors = <&tsu 0>;
    };
};
```

```

        trips {

            sensor_crit: sensor-crit {

                temperature = <110000>;          <-- Change this value

                hysteresis = <1000>;

                type = "critical";

            };

        };

    };

};

```

Figure 4-1 Device tree source file of RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five Group

```

thermal-zones {

    emergency {
        polling-delay = <1000>;
        on-temperature = <110000>; ← Change this value
        off-temperature = <95000>; ← Change this value
        target_cpus = <&cpu1 &cpu2 &cpu3>;
        status = "disabled";
    };

    sensor_thermal0: sensor-thermal0 {
        polling-delay-passive = <250>;
        polling-delay = <1000>;
        thermal-sensors = <&tsu0 0>;

        trips {
            sensor0_crit: sensor0-crit {
                temperature = <120000>; ← Change this value
                hysteresis = <1000>;
                type = "critical";
            };
        };
    };

    sensor_thermal1: sensor-thermal1 {
        polling-delay-passive = <250>;
        polling-delay = <1000>;
        thermal-sensors = <&tsu1 0>;

        trips {
            sensor1_crit: sensor1-crit {
                temperature = <120000>; ← Change this value
                hysteresis = <1000>;
                type = "critical";
            };
        };
    };

};

```

Figure 4-2 Device tree source file of RZ/V2N Group


```

thermal-zones {
    emergency {
        polling-delay = <1000>;
        on-temperature = <110000>; ← Change this value
        off-temperature = <95000>; ← Change this value
        target_cpus = <&cpu1 &cpu2 &cpu3>;
        status = "disabled";
    };

    cpu-thermal {
        polling-delay = <1000>;
        polling-delay-passive = <250>;
        thermal-sensors = <&tsu>;

        cooling-maps {
            map0 {
                trip = <&target>;
                cooling-device = <&cpu0 0 3>, <&cpu1 0 3>,
                               <&cpu2 0 3>, <&cpu3 0 3>;
                contribution = <1024>;
            };
        };
        trips {
            target: trip-point {
                temperature = <95000>;
                hysteresis = <1000>;

                type = "passive";
            };
            sensor_crit: sensor-crit {
                temperature = <120000>; ← Change this value
                hysteresis = <1000>;
                type = "critical";
            };
        };
    };
};

```

Figure 4-3 Device tree source file of RZ/G3E Group

4.3 Setting for Interrupt or Polling Mode

By default, the driver will use Polling mode to update temperature of thermal zone. Please modify device tree to use interrupt if desire.

```
thermal-zones {
    sensor_thermal: sensor-thermal {
        polling-delay-passive = <250>;

        polling-delay = <1000>;          <-- Change this value

        sustainable-power = <3874>;

        thermal-sensors = <&tsu 0>;

        cooling-maps {
            map0 {
                trip = <&target>;

                cooling-device = <&cpu0 0 2>;

                contribution = <1024>;
            };
        };

        trips {
            target: trip-point {
                temperature = <100000>;

                hysteresis = <1000>;

                type = "passive";
            };
        };
    };
};
```

Note: if interrupt mode is default change value to "0".

Figure 4-4 Configuration Example for Polling Support of RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five Group

```

thermal-zones {
    emergency {
        polling-delay = <1000>;
        on-temperature = <110000>;
        off-temperature = <95000>;
        target_cpus = <&cpu1 &cpu2 &cpu3>;
        status = "disabled";
    };

    sensor_thermal0: sensor-thermal0 {
        polling-delay-passive = <250>;
        polling-delay = <1000>;
        thermal-sensors = <&tsu0 0>;

        trips {
            sensor0_crit: sensor0-crit {
                temperature = <120000>;
                hysteresis = <1000>;
                type = "critical";
            };
        };
    };

    sensor_thermal1: sensor-thermal1 {
        polling-delay-passive = <250>;
        polling-delay = <1000>;
        thermal-sensors = <&tsu1 0>;

        trips {
            sensor1_crit: sensor1-crit {
                temperature = <120000>;
                hysteresis = <1000>;
                type = "critical";
            };
        };
    };
};

```

Note: if interrupt mode is default change value to "0".

Figure 4-5 Configuration Example for Polling Support of RZ/V2N Group

```

thermal-zones {
    emergency {
        polling-delay = <1000>;
        on-temperature = <110000>;
        off-temperature = <95000>;
        target_cpus = <&cpu1 &cpu2 &cpu3>;
        status = "disabled";
    };

    cpu-thermal {
        polling-delay = <1000>; ←Change this value
        polling-delay-passive = <250>;
        thermal-sensors = <&tsu>;

        cooling-maps {
            map0 {
                trip = <&target>;
                cooling-device = <&cpu0 0 3>, <&cpu1 0 3>,
                               <&cpu2 0 3>, <&cpu3 0 3>;
                contribution = <1024>;
            };
        };
        trips {
            target: trip-point {
                temperature = <95000>;
                hysteresis = <1000>;

                type = "passive";
            };
            sensor_crit: sensor-crit {
                temperature = <120000>;
                hysteresis = <1000>;
                type = "critical";
            };
        };
    };
};

```

Note: if interrupt mode is default change value to "0".

Figure 4-6 Configuration Example for Polling Support of RZ/G3E Group

5. Integration

5.1 Directory Configuration

The Thermal driver software directory configuration is shown below.

Note: r9a07g044.dtsi for RZ/G2L and RZ/G2LC, r9a07g043.dtsi for RZ/G2UL and RZ/Five, r9a07g054.dtsi for RZ/V2L, r9a09g056.dtsi for RZ/V2N, r9a09g047.dtsi for RZ/G3E.

```
arch/arm64/boot/dts/renesas/
├── r9a07g044.dtsi
├── r9a07g054.dtsi
├── r9a07g043.dtsi
└── r9a09g047.dtsi
In kernel v5.10:
drivers/thermal/
├── rzg2l_thermal.c
In kernel v6.1:
drivers/thermal/renesas/
├── rzg2l_thermal.c
└── rzg3e_thermal.c
```

Figure 5-1 Directory Configuration of RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five, RZ/G3E Group

```
arch/arm64/boot/dts/renesas/
├── r9a09g056.dtsi
drivers/thermal/
├── rzv2h_thermal.c
```

Figure 5-2 Directory Configuration of RZ/V2N Group

5.2 Integration Procedure

To enable the functions of this module, make the following setting in Kernel Configuration.

```
Device Drivers --->
[*] Thermal drivers --->
    <*> Renesas RZ/G2L thermal driver
```

Figure 5-3 Kernel Configuration of RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five Group

```
Device Drivers --->
[*] Thermal drivers --->
    <*> Renesas RZ/V2H thermal driver
```

Figure 5-4 Kernel Configuration of RZ/V2N Group

Device Drivers --->

[*] Thermal drivers --->

<*> Renesas RZ/G3E thermal driver

Figure 5-5 Kernel Configuration of RZ/G3E Group

5.3 Option Setting

5.3.1 Module Parameters

There are no module parameters.

5.3.2 Kernel Parameters

There are no kernel parameters.

5.4 Temperature calculation

5.4.1 Calculation for RZ/G2L Group, RZ/V2L and RZ/Five

TSU temperature calculation flow of RZ/G2L, RZ/G2LC, RZ/G2UL, RZ/V2L, RZ/Five Group:

	Description	accuracy
TSCode[1]~[8]	AD conversion digital value (register value of TSU_SAD) Value (12bit) captured 1 to 8 times	12bit unsigned
TSCode[Ave]	Mean value (12bit) of the above 8 data	12bit unsigned
OTPTSUTRIM0_REG	Calibration data (125 ° C) Read the correction values for use in calibration from registers OTPTSUTRIM0_REG and use the 3 formular to calculate T.	12bit unsigned
OTPTSUTRIM1_REG	Calibration data (-40 ° C) Read the correction values for use in calibration from registers OTPTSUTRIM1_REG and use the 3 formular to calculate T.	12bit unsigned
T	Temperature [°C]	Please specify on the Software side.

① Calculate the average value of TSU_SAD 8 times

$$\text{TSCode[Ave]} = (\text{TSCode[1]} + \dots + \text{TSCode[8]}) / 8$$

② Curvature correction

$$\text{D[Sensor]} = \text{TSCode[Ave]} / (1 + \text{TSCode[Ave]} * 0.000013)$$

③Temperature calculation

$$T = (D[\text{Sensor}] - \text{OTPTSUTRIM1_REG}) * (165 / (\text{OTPTSUTRIM0_REG} - \text{OTPTSUTRIM1_REG})) - 40$$

5.4.2 Calculation for RZ/V2N and RZ/G3E

TSU temperature calculation flow of RZ/V2N Group and RZ/G3E Group:

$$T(^{\circ}\text{C}) = \left(\frac{e - d}{c - b} \right) \times (a - b) + d$$

After acquiring the temperature, the compensated temperature T ($^{\circ}\text{C}$) must be calculated from the value (a) of the OUT12BIT_TS bits of the sensor code read register and the values (b) to (c) read from the SYS register.

Follow the procedure below to calculate the compensated temperature. (Maximum error is $\pm 5^{\circ}\text{C}$)

Remarks: $b = \text{priv->trmval0_11_0} = \text{SYS: OTPTSUnTRMVAL0}[11:0]$

$c = \text{priv->trmval1_11_0} = \text{SYS: OTPTSUnTRMVAL1}[11:0]$

$d = \text{TSU_D} = -41$

$e = \text{TSU_E} = 126$

1. Read the converted code form Sensor Code Read Register

$a = \text{readl}(\text{priv->base} + \text{TSU_SCRR}) \ \& \ \text{CTEMP_MASK}$

2. Calculate the value of the operation $(e - d) \times (a - b)$

$\text{val0} = (\text{TSU_E} - \text{TSU_D}) * (a - \text{priv->trmval0_11_0})$

3. Calculate the value of the operation $(c - b)$

$\text{val1} = (\text{priv->trmval1_11_0} - \text{priv->trmval0_11_0})$

4. Temperature calculation

$T = (\text{val0} / \text{val1}) + \text{TSU_D}$

Revision History	Linux Interface Specification Device Driver Thermal Sensor User's Manual: Software
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Rev.	Date	Description	
		Page	Summary
0.50	Apr. 30, 2021	—	First Edition issued
1.0	Jul. 15, 2021	—	No modification, keep version to keep consistent with other documents
1.1	Sep. 15, 2021	—	Merge RZ/G2L driver manual with RZ/V2L
1.2	Feb. 15, 2022	—	Add RZ/G2UL, RZ/G2LC device.
1.3	April. 15, 2022	—	Update Calibration data, revision 1.3
1.4	May. 31, 2022	—	Update kernel 5.10, revision 1.4
1.5	Jun. 24, 2022	—	Add RZ/Five
1.6	Sep. 15, 2022	—	Update new information of TSU
1.7	Dec. 15, 2022	—	No modification, change version to keep consistent with other documents
1.8	Mar. 15, 2023	—	No modification, change version to keep consistent with other documents
1.9	May. 30, 2025	1	Add MPU information support for both kernel versions v5.10 and v6.1. Correct 1.2 Function
1.10	Jun 30, 2025	—	Add RZ/V2N information
1.11	Jul. 22, 2025	—	Add RZ/G3E information

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