Temperature Gradient
SLG47011

Abstract

This application note describes how to use the AnalogPAK SLG47011 to design a temperature gradient application. This application note comes complete with a design file that can be found in the Reference section.

Contents

1. Terms and Definitions

Multichannel DCMP Multichannel Digital Comparator

PGA Programmable Gain Amplifier

2. References

For related documents and software, please visit:

AnalogPAK™ | Renesas

Download our free Go Configure Software Hub [1] to open the design file [2] and view the proposed circuit design. Use the AnalogPAK development tools to freeze the design into your own customized IC in a matter of minutes. Renesas Electronics provides a complete library of application notes [3] featuring design examples, as well as explanations of features and blocks within the Renesas IC.

[1] Go Configure Software Hub, Software Download and User Guide, Renesas Electronics
[2] AN-CM-402 Temperature Gradient.aap, AnalogPAK Design File, Renesas Electronics
[3] Application Notes, GreenPAK Application Notes Webpage, Renesas Electronics

3. Introduction

The input data in a Temperature Gradient application consists of a temperature value from an internal temperature sensor which can be used in applications where the rate of change of temperature needs to be detected (e.g., refrigerators).

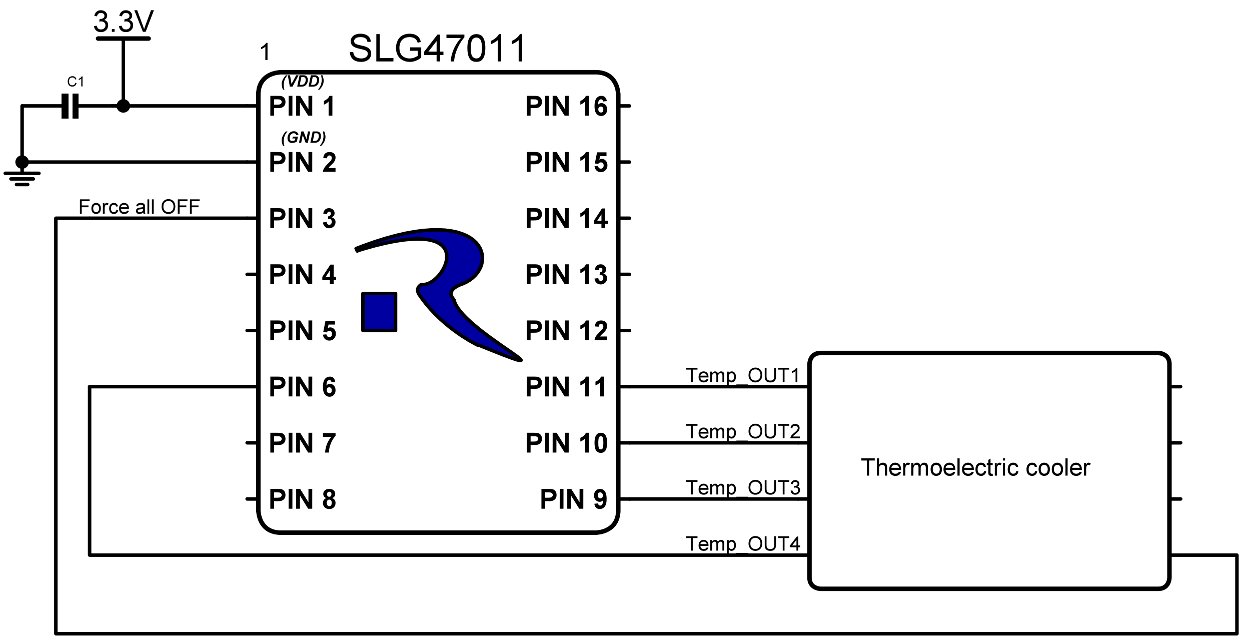

Figure 1. System Diagram

4. AnalogPAK Design

In this design, the temperature gradient (rate of change) with four levels of detection provided by a digital comparator, takes the current temperature value and stores it in Buffer0. The previous temperature value is stored in Buffer1 and the difference between the current and previous values are compared by the Multichannel DCMP. Adjusting the hysteresis value can set the detection speed of the rise or drop in temperature and the four outputs are used to find the gradient.

On the power controller, Retention Mode can be performed during non-measurement periods through mode switching. In this mode, the quiescent current is less than 5 μA. This design maintains data storage and saves power.

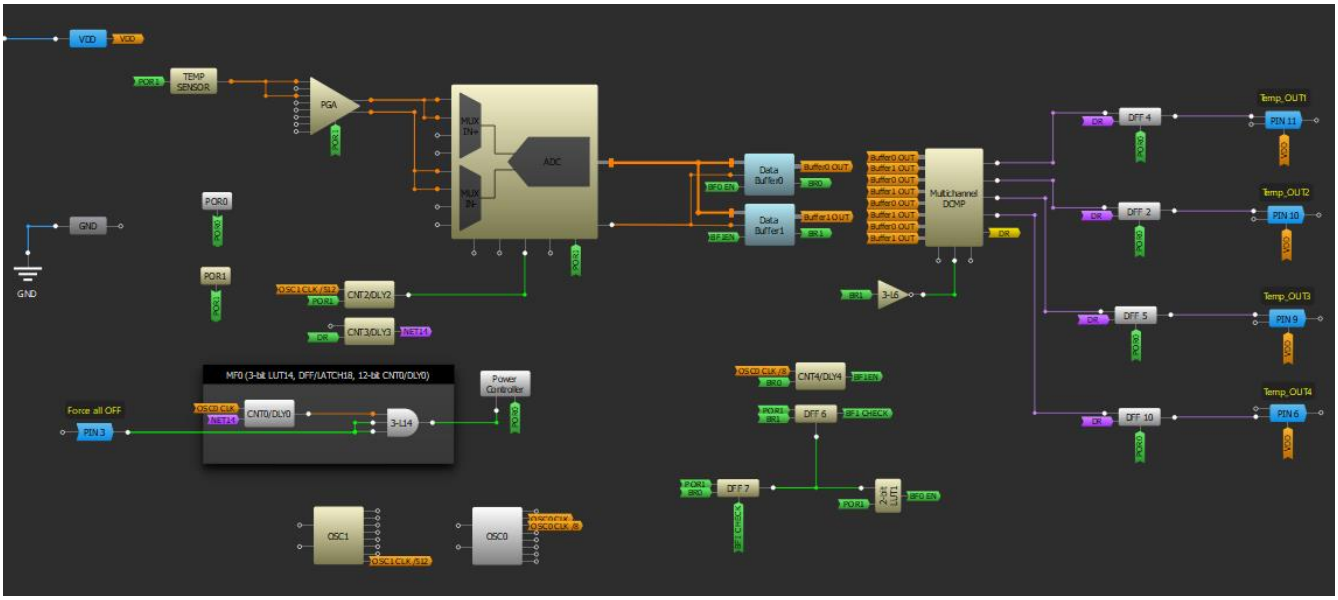

Figure 2. GreenPAK Designer Schematic of the Temperature Gradient application

4.1 Temperature Sensor

The SLG47011 has an Analog Temperature sensor (TS) with an output voltage linearly proportional to the Centigrade temperature. The TS output is selected as a source to the ADC or ACMP positive input. The TS is rated to operate over a -40 °C to 85 °C temperature range. The error in the entire temperature range does not exceed ±1.5 % and the TS output voltage variation over V_{DD} at constant temperature is less than ±1.5 %.

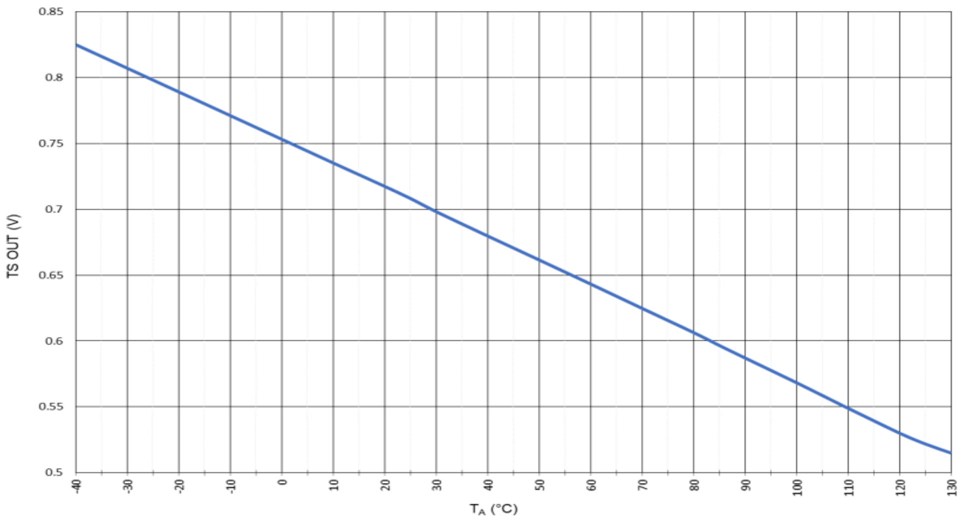

Figure 3. TS Output vs. Temperature, V_{DD} = 1.71 V to 3.6 V

4.2 PGA Configuration

In temperature sensing applications, the PGA of the SLG47011 is configured to operate in mode 6. The value from the internal temperature is converted into a voltage and the signal is sent to the ADC through the buffer.

The PGA channel settings are shown in Figure 4.

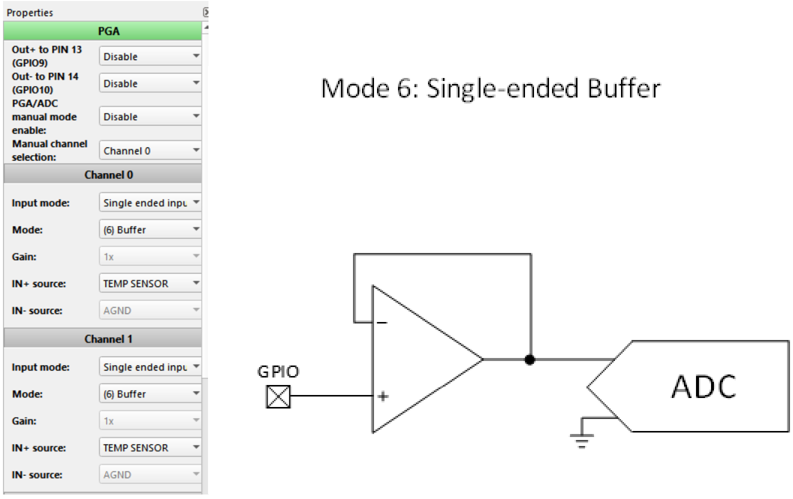

Figure 4. PGA configuration using channel 0 and channel 1 to compare the previous and current temperature.

4.3 ADC Configuration

The ADC is configured to use OSC1 with the 20 MHz clock selected. Please note that the Clock divider is set to the /16 divider (31.25 kps). Since the temperature is detected in sequence, this setting will allow each channel to sense the delay.

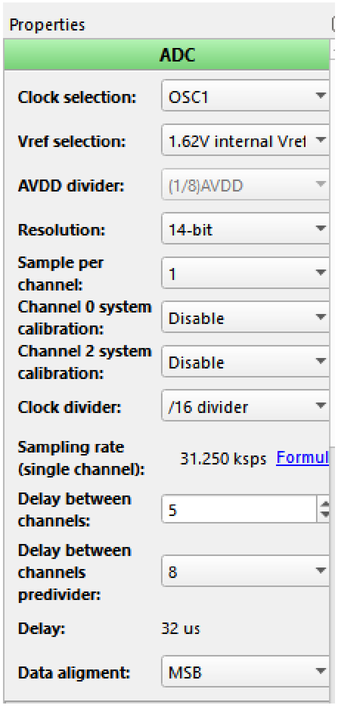

Figure 5. ADC Configuration

4.4 Data Buffer0/1 Configuration

Mode: Moving Average

Length: 1 word

Buffer ready: 1

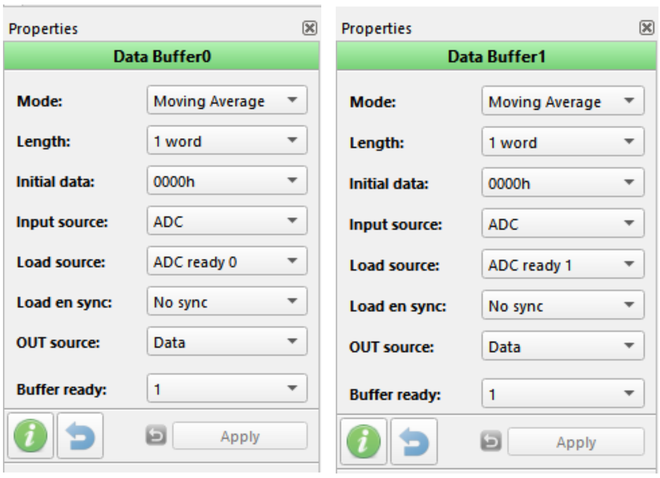

Figure 6. Data Buffer0 and Data Buffer1 Configuration

4.5 Multichannel DCMP Configuration

Mode: Sequence conversion Mode

Sync enable: Async

Eanble Source: Matrix out

Compare selection: Greater than

IN+ source: Buffer0 data

IN- source: Buffer1 data

Hysteresis value: Adjust according to gradient requirement

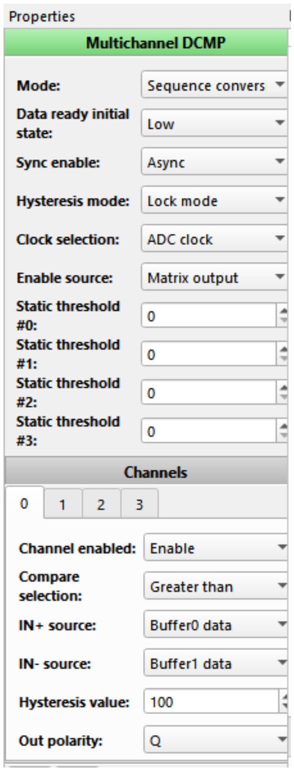

Figure 7. Multichannel DCMP Configuration

4.5.1. Adjusting the Hysteresis value:

The hysteresis value is calculated based on the slope of temperature change versus time according to the following formulas.

In section 4.1, it is mentioned that the following values are obtained based on the temperature versus voltage output of the SLG47011's internal temperature sensor:

$$V_{TS\ OUT} = 0.0019\ [{}^{V}/_{°C}]$$

In temperature gradient application designs, two design parameters must be known. The first is the temperature change per second and the section is the detection interval.

$$Temperature\ change\ per\ second = \frac{\Delta \text{Temperature}}{\Delta \text{Time}}\ [{}^{\Delta T}/_{Sec}]$$

Next, the temperature change per second is multiplied by the detection time and then further multiplied by the voltage value represented by ° C per degree to obtain the Hysteresis voltage change HYS (α).

$$HYS(\alpha) = Temperature\ change\ per\ second\ \times\ Detection\ interval\ \times\ V_{TS\ OUT}$$

Where the detection interval is the interval time between front and rear temperature detection.

Lastly, we divide the obtained HYS (α) by the ADC reference voltage value Vref (1.62 V) and multiply it by the ADC resolution (14-bit = 16383) to get the design threshold Hysteresis value.

$$Hysteresis\ Value = \frac{HYS(\alpha)}{Vref(1.62V)} \times\ 16383\ (ADC\ resolution, 14bits)$$

4.6 Operating Instructions

The design operates in three stages:

First, the data from the TEMP SENSOR is written to Buffer0, and after a specified delay, which is configured using a One shot (CNT/DLY4), the data from the TEMP SENSOR is written to Buffer1. The data from Buffer0 and Buffer1 are compared by the Multichannel DCMP during this cycle. Depending on the difference between the data in Data Buffer0 and Data Buffer1, we can determine the rate of temperature change.

The following tests use a range of voltage values which are used as a temperature change simulation, and four groups of experiments were designed to verify the actual application examples.

Test conditions:

Temperature range	25 ° C – 40 ° C	25 ° C – 60 ° C	25 ° C – 80 ° C	25 ° C – 100 ° C
Voltage range	705 mV – 667 mV	705 mV – 638 mV	705 mV – 600 mV	705 mV – 562 mV
Time	6 seconds			
Hysteresis value	Temp_OUT1: 100 Temp_OUT2: 300 Temp_OUT3: 500 Temp_OUT4: 600			

5. Functional Waveforms

Channel 1 (yellow/top line) – TS Output
D0 – Temp_OUT1
D1 – Temp_OUT2
D2 – Temp_OUT3

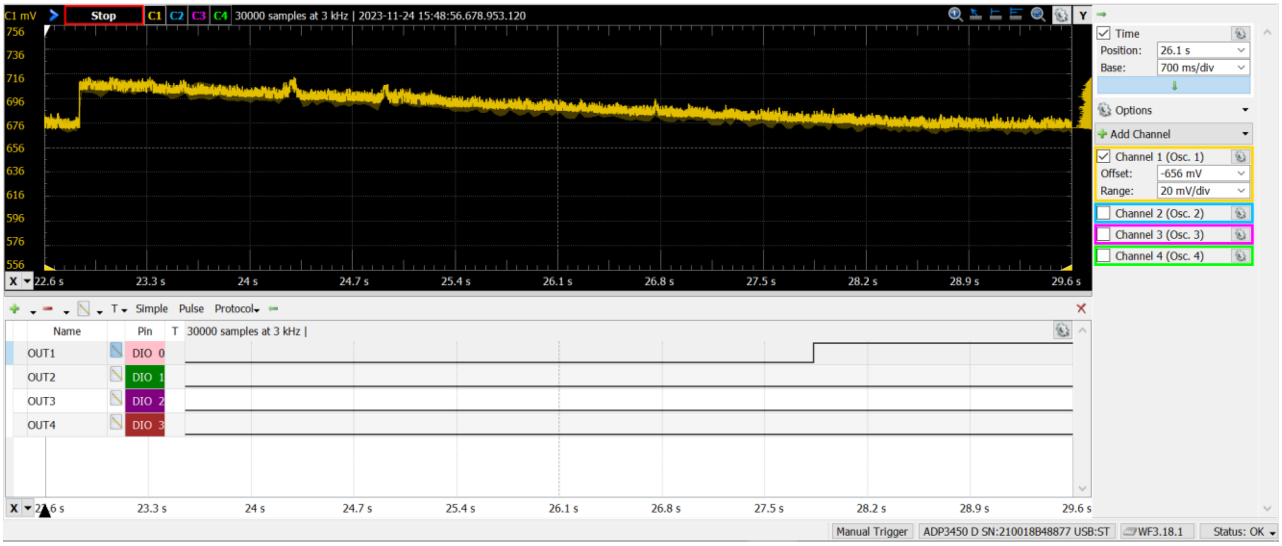

Figure 8. Temperature rise 25 °C – 40 °C

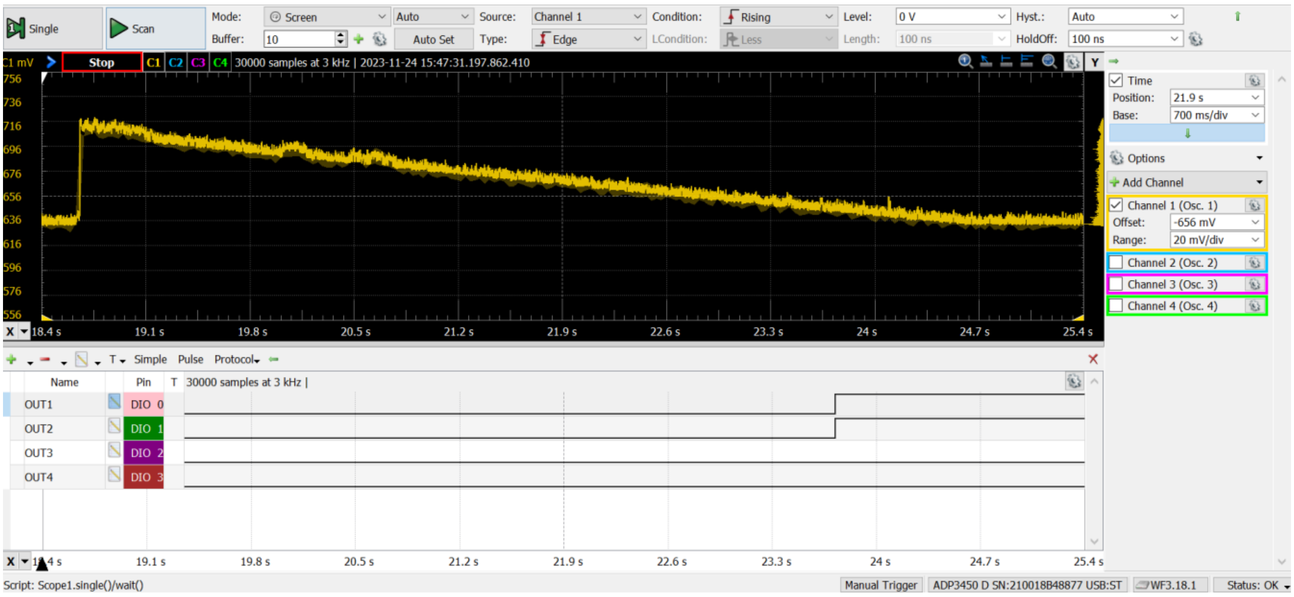

Figure 9. Temperature rise 25 °C – 60 °C

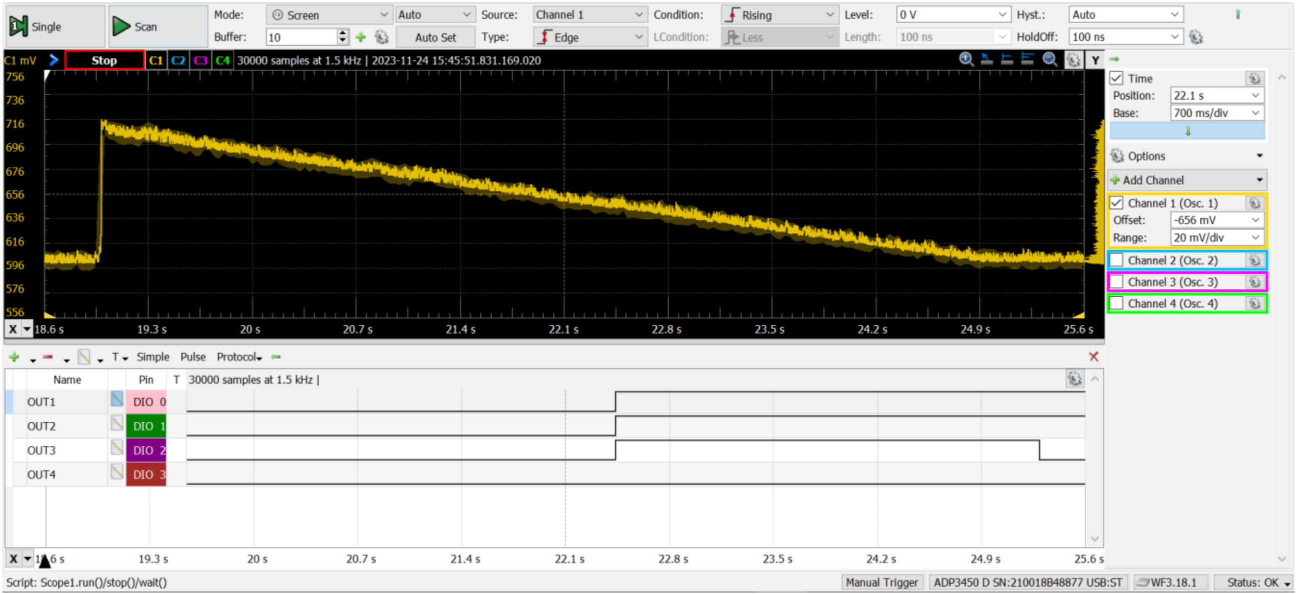

Figure 10. Temperature rise 25 °C – 80 °C

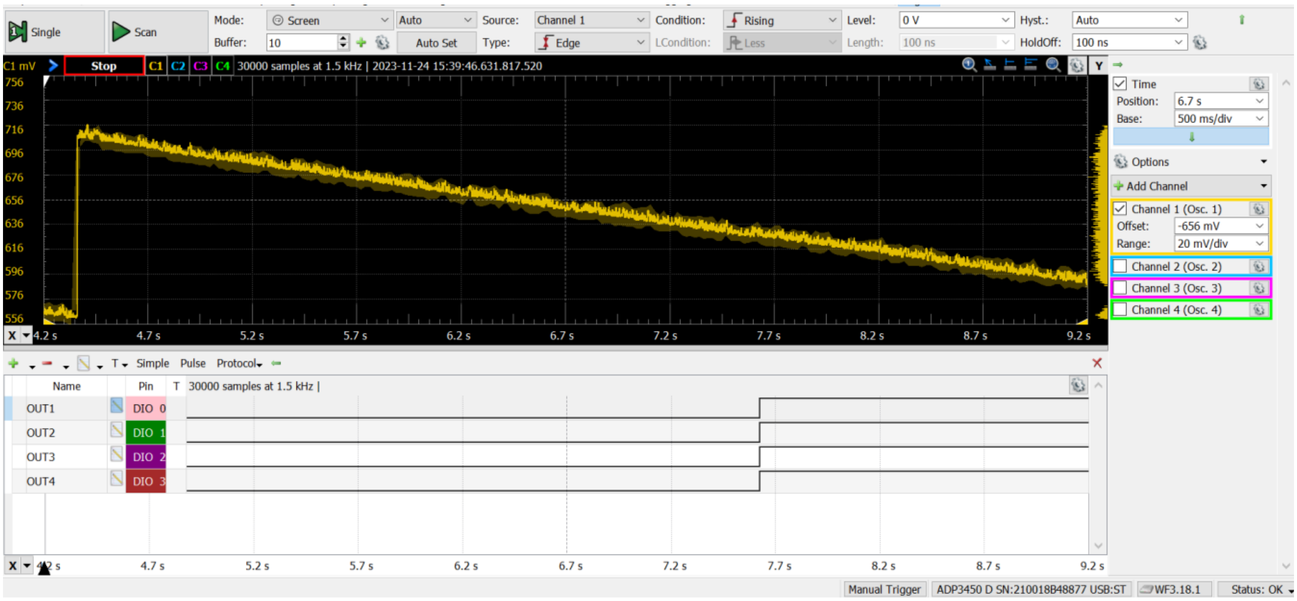

Figure 11. Temperature rise 25 °C – 100 °C

6. Conclusion

From the above four test results, the yellow line is the voltage value corresponding to the internal temperature sensing when the temperature rises, the test time is all 6 seconds, the range of temperature rise affects the slope. The first test temperature of 25° C to 40° C has a relatively slow rising slope and can only trigger the output of OUT1. The fourth test temperature of 25° C to 100° C, the rising slope is steeper and Temp_OUT1 - Temp_OUT4 are all triggered.

Therefore, it can be known from the 4 test results that the number of OUT will trigger different outputs as the temperature rise slope becomes slower and steeper, and by adjusting the Hysteresis value in the Multichannel DCMP parameter, different slope detection can be set.

7. Revision History

Revision	Date	Description
1.00	November 5, 2024	Initial release

IMPORTANT NOTICE AND DISCLAIMER

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit www.renesas.com/contact-us/.