

Temperature Slew Rate Warning Overview



Andrew Mason

Abstract

System designs continue to push the boundaries of performance in every aspect including high temperature operation. It is important not only to know the current temperature but also be able to predict the temperature based on sudden load or performance changes. The Temperature Slew Rate Warning gives system designers a new tool to prevent thermal stress and degradation by allowing for predictive temperature control.

Table of Contents

Abstract	1
1 Introduction	2
2 Concept	3
3 Design Considerations	4
3.1 Conversion Period Impact.....	4
3.2 Impact of Conversion Period Error.....	5
4 Design Example	5
4.1 Design Requirements.....	5
4.2 Detailed Design Procedure.....	6
5 Summary	7
6 Temperature Slew Rate Warning Device List	7

List of Figures

Figure 1-1. Traditional Threshold Alert.....	2
Figure 2-1. Slew Rate Warning.....	3
Figure 3-1. Slew_Rate with 1 Second Conversion Period.....	4
Figure 3-2. Slew_Rate with 0.5 Second Conversion Period.....	4
Figure 4-1. Design Example.....	5

List of Tables

Table 4-1. Example Conversion Period Settings.....	6
Table 4-2. Device Settings.....	6
Table 6-1. Slew Rate Warning Devices.....	7

Trademarks

All trademarks are the property of their respective owners.

1 Introduction

Temperature control traditionally uses min or max temperature thresholds to take corrective action using the system's thermal cooling system or shut-down devices. This process does not address over temperature conditions that occur between temperature conversion samples, or allow systems to predict thermal issues before they occur. Additionally, as system designs become more compact and higher power, thermal limit excursions can occur quicker leading to system damage.

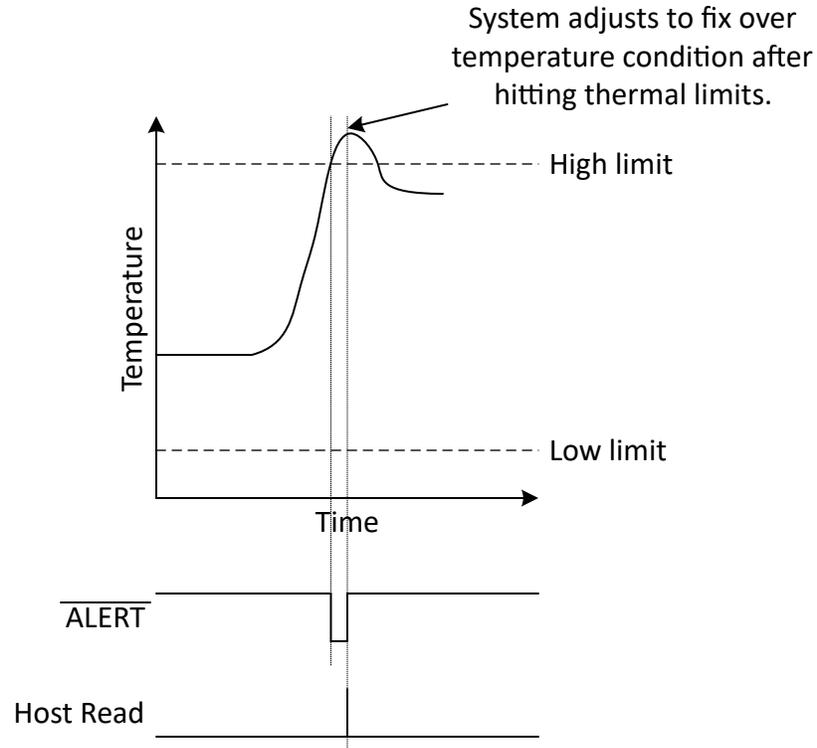


Figure 1-1. Traditional Threshold Alert

2 Concept

The Temperature Slew Rate Warning continuously monitors temperature change over time and calculates the slew rate to alert the system of a rapid temperature rise. This process enables systems to take corrective action before the operating temperature exceeds its intended range. [Figure 2-1](#) shows a visual representation of the slew rate warning $\overline{\text{ALERT}}$ response to a rapid temperature rise.

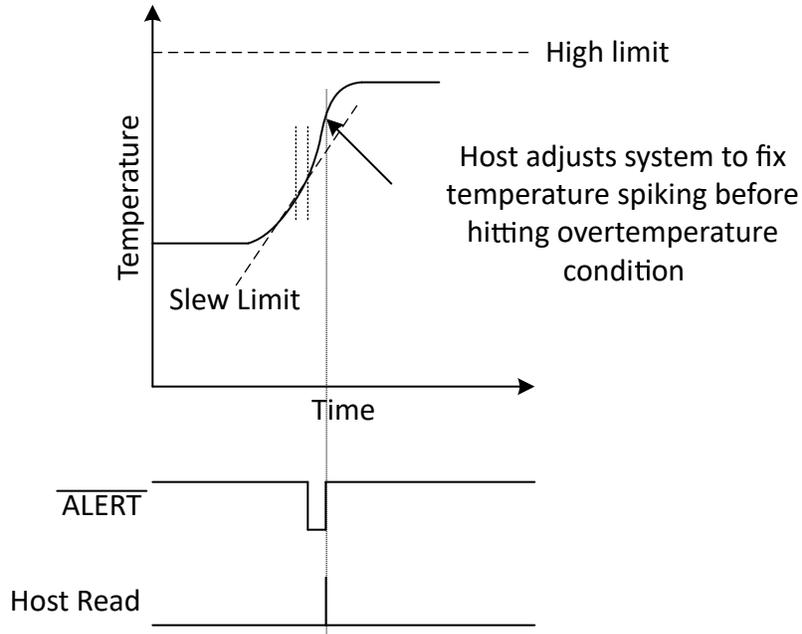


Figure 2-1. Slew Rate Warning

3 Design Considerations

The slew rate warning feature has two parameters which can impact how the feature performs. This section discusses how device operation can impact the feature functionality.

3.1 Conversion Period Impact

The slew rate warning will compare the most recent temperature conversion result with the previous temperature conversion result. Figure 3-1 shows how the slew rate feature responds to rapid temperature change with a 1 second conversion rate. When designing with the slew rate feature, it is important to consider that the temperature sensor measuring the slew rate can only respond as fast as the conversion period. In this example the sensor reports a peak slew rate of 7.5°C/s.

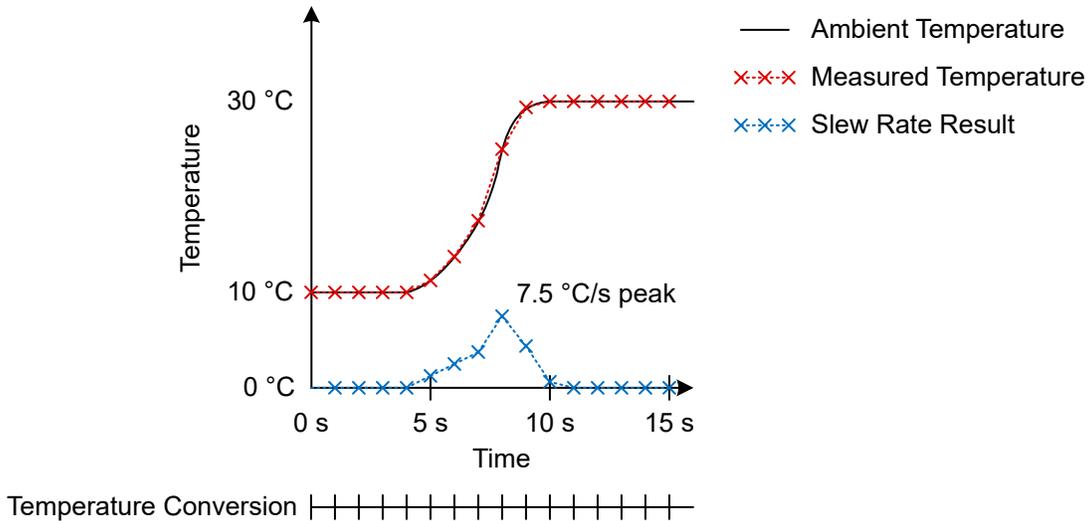


Figure 3-1. Slew_Rate with 1 Second Conversion Period

With the same ambient temperature profile and a faster conversion period, the slew rate warning can yield more accurate and granular results of the ambient temperature slew profile. Figure 3-2 depicts the resulting waveform if the conversion period is adjusted to 0.5 seconds instead of 1 second. With this setting the device reports a peak of 10°C/s with the same temperature profile.

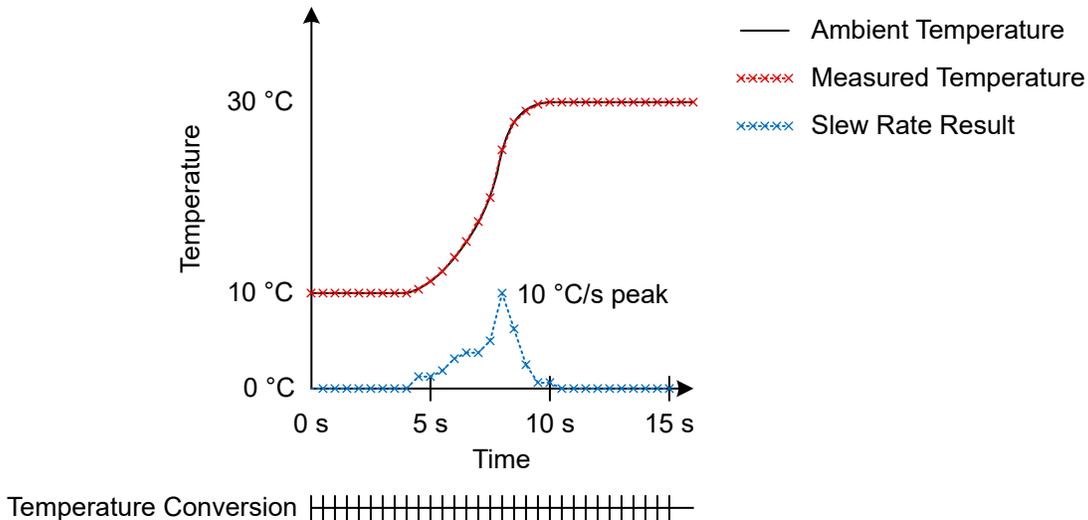


Figure 3-2. Slew_Rate with 0.5 Second Conversion Period

3.2 Impact of Conversion Period Error

The slew rate warning feature utilizes the known conversion period for the calculation of the slew rate based on the device setting. If there is an error of the conversion period (t_{CONV_PERIOD}) due to a non-ideal oscillator, the actual conversion period may be slightly longer or shorter, resulting in error of the slew rate calculation. Equation 1 shows the equation for calculating the slew rate with t_{CONV_PERIOD} as the time period over which the calculation takes place. If t_{CONV_PERIOD} is 90% of the expected value, the slew rate calculation will be 11% faster than the real value, calculated with Equation 2. This can be accounted for in a similar manner to temperature accuracy with proper guardbanding, as shown in the Design Example.

$$SlewRate = \frac{(T_{RECENT} - T_{RECENT - 1})}{t_{CONV_PERIOD}} \tag{1}$$

$$SlewRate_{Adjusted} = \frac{(T_{RECENT} - T_{RECENT - 1})}{t_{CONV_PERIOD} * (1 \pm \text{timing error})} \tag{2}$$

4 Design Example

This section will give an example implementation of the slew rate warning feature.

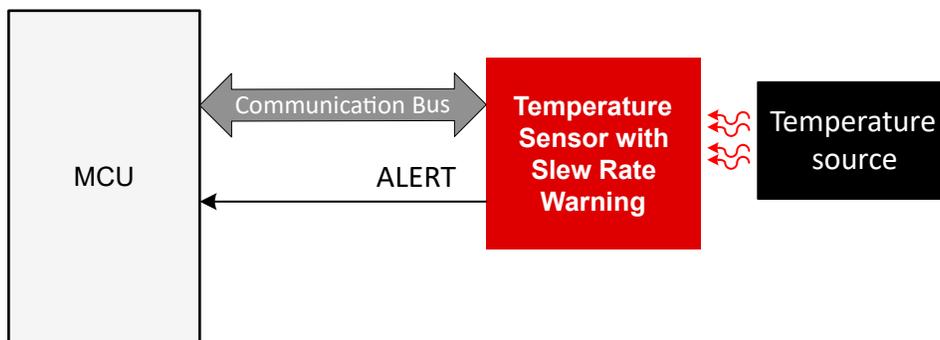


Figure 4-1. Design Example

4.1 Design Requirements

In this example a power FET driving a brushless DC motor cannot operate above 125 °C, and it is known that there is a potential issue with the FET if the temperature rises faster than 20 °C/s. This rapid change in temperature will lead to a runaway thermal condition unless the current is reduced.

The accuracy of the temperature sensor should remain within 1 °C throughout its temperature range. And the temperature sensor has a conversion period error of 15 %. A timing error of 15 % would indicate that for a given conversion period setting, the conversion period can be ±15 % of the setting.

4.2 Detailed Design Procedure

With a desired system limit of 20 °C/s and a conversion period timing error of 15 %, the Slew Rate Limit setting can be calculated as shown in the following equations. To ensure the warning triggers by 20 °C/s, the ±15 % timing error must be factored into the calculation. Using the below equations we get a Slew Rate Limit of 17.4 °C/s.

$$\begin{aligned}
 SlewRate &= \frac{(T_{RECENT} - T_{RECENT-1})}{t_{CONV_PERIOD}} = 20 \\
 SlewRate_{Adjusted} &= \frac{(T_{RECENT} - T_{RECENT-1})}{t_{CONV_PERIOD} * (1 + \text{timing error})} = \frac{(T_{RECENT} - T_{RECENT-1})}{t_{CONV_PERIOD} * (1 + 0.15)} = \frac{(T_{RECENT} - T_{RECENT-1})}{t_{CONV_PERIOD}} * \frac{1}{(1 + 0.15)} \\
 SlewRate_{Adjusted} &= 20 * \frac{1}{(1 + 0.15)} = 17.4
 \end{aligned} \tag{3}$$

With a Slew Rate Limit setting of 17.4 °C/s, minimum and maximum slew rates that will trigger an alert can be determined by Equation 4. A setting of 17.4 °C/s will trigger an alert at a minimum slew rate of 14.79 °C/s, a typical slew rate of 17.4 °C/s, and a maximum slew rate of 20 °C/s. This ensures that the warning will always trigger before reaching the 20 °C/s design requirement.

$$\begin{aligned}
 SlewRate_{Min} &= \frac{(T_{RECENT} - T_{RECENT-1})}{t_{CONV_PERIOD} * (1 - \text{timing error})} = 20 * \frac{1}{(1 - 0.15)} = 14.79 \text{ °C/s} \\
 SlewRate_{Max} &= \frac{(T_{RECENT} - T_{RECENT-1})}{t_{CONV_PERIOD} * (1 + \text{timing error})} = 20 * \frac{1}{(1 + 0.15)} = 20 \text{ °C/s}
 \end{aligned} \tag{4}$$

The second outlined requirement is the system must react within 200 ms to the temperature spike occurring. The list of possible conversion period settings are shown in Table 4-1. From this table it is acceptable to choose between options 31.25 ms (1h), 62.5 ms (2h), or 125 ms (3h). This would allow the device to detect and alert the system faster than 200 ms. Setting 0h cannot be chosen as the slew rate warning requires a time delay between temperature conversions.

Table 4-1. Example Conversion Period Settings

Setting	Conversion Period
0h (No delay between conversion)	5.5 ms
1h	31.25 ms / 32 Hz
2h	62.5 ms / 16 Hz
3h	125 ms / 8 Hz
4h	250 ms / 4 Hz
5h	500 ms / 2 Hz
6h	1 s / 1 Hz
7h	2 s / 0.5 Hz

The device settings for this design example are shown in Table 4-2.

Table 4-2. Device Settings

Setting	Conversion Period
Slew Rate Limit	17.4 °C/s
Conversion Period	125 ms

5 Summary

The Temperature Slew Rate Warning is an effective tool to detect runaway thermal conditions and alert system controllers to moderate thermal performance. By utilizing the steps outlined previously the feature can be tailored to fit multiple use cases.

6 Temperature Slew Rate Warning Device List

Table 6-1 shows the TI temperature sensors with the Temperature Slew Rate Warning feature.

Table 6-1. Slew Rate Warning Devices

Part Number	Device Type	Interface	Alert pin included	Temperature Accuracy (Max)
TMP126	Local	SPI	Yes	0.3 °C
TMP126-Q1	Local	SPI	Yes	0.3 °C
TMP114	Local	I ² C	No	0.3 °C

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2022, Texas Instruments Incorporated