

# How to Design Alert Overtemperature and Undertemperature Systems



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## ABSTRACT

This article presents an in-depth guide in selecting an alert function, and all configurations available within TI's temperature portfolio. Texas Instruments (TI) temperature sensors include a comprehensive set of alert and interrupt features designed to help systems detect, respond to, and protect against thermal events in real time. Across the portfolio, these devices support programmable temperature thresholds, hysteresis, and comparison logic that can assert alert outputs when measured temperature exceed or fall below defined limits. Alerts can be configured for over-temperature, under-temperature, or windowed conditions. The alert signals are available as active-high or active-low signals. The alert signals are offered as either a push-pull or open drain output. Together, these alert capabilities enable proactive thermal management, fault detection, and system safety across industrial, automotive, and customer applications while minimizing firmware overhead and response time. This document highlights and summarizes all features available for alert functionality across TI's full temperature sensor portfolio and finalize a comparison between top selling devices.

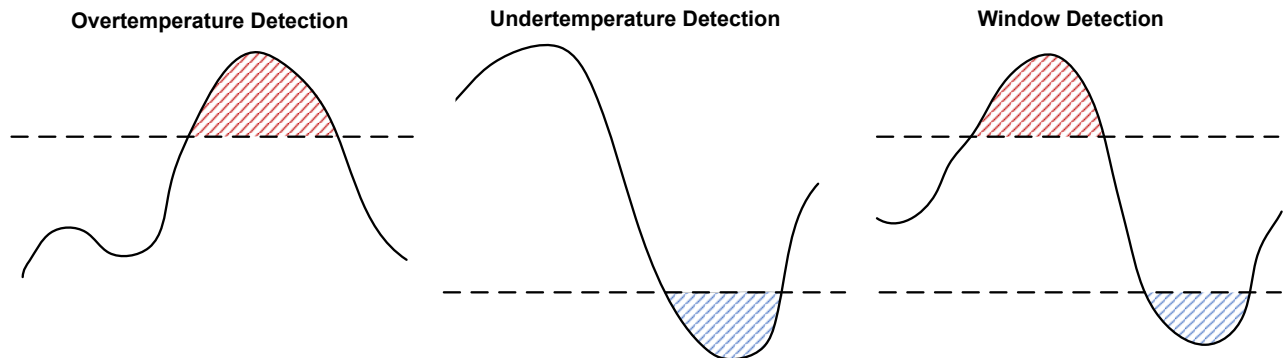


Figure 1-1. Different Types of Alerts

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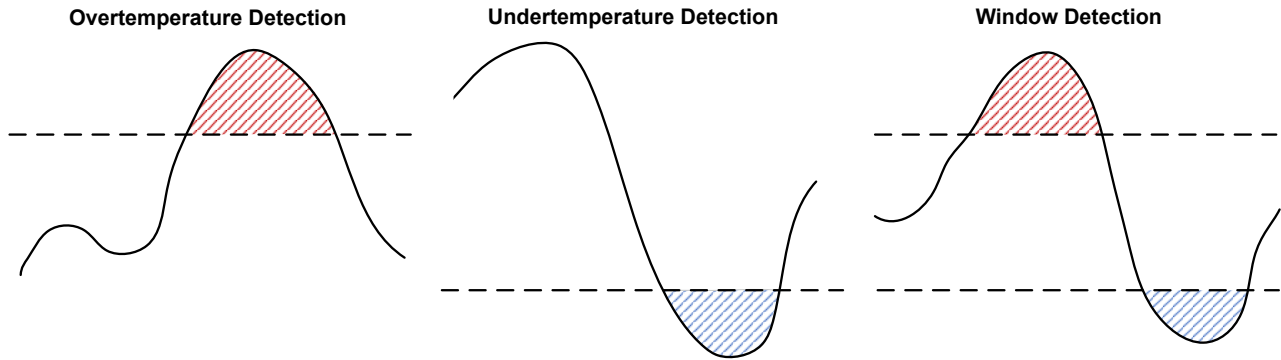
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## 1 Introduction

Uncontrolled thermal events can lead to premature component failure, battery hazards, and compromised system reliability. To mitigate these risks, modern electronic systems incorporate temperature sensors with alert functionality capable of autonomously triggering cooling, shutdown, or alarm responses. Depending on the application, alert behavior may be optimized for safety, performance, or reliability requirements. Common applications for the use of alert signals are shown in [Table 1-1](#). This application note introduces the alert functionality available across TI's temperature sensors portfolio and provides guidance for selecting and configuring devices for thermal protection applications. Topics including hysteresis and different output configurations will be addressed in this document. The document reviews common alert implementations, compares key device features, and presents practical design considerations and circuit examples to simplify system integration.



**Figure 1-1. Different Types of Alerts**

**Table 1-1. Different Use Cases for Each Alert Type**

Alert Type	Overtemp	Undertemp	Window
Example Application	Thermal protection for processing components such as processors, power electronics, and other ICs	Low-temp protection for Thin Film Transistor (TFT) displays	Charge cycle and storage monitoring for Lithium-ion battery systems
Example Alert Limits	85C to 125C	-30C	0C and 45C
Example Device	TMP4718	TMP390	TMP115

## 1.1 Design Workflow

Below are steps in how to select a device for alert functionality. Sections within this app note are linked within the steps.

1. Determine your temperature parameters: Determine your target temperature limits and the total number of thresholds required.
2. Establish the hysteresis value: Identify the appropriate **HYSTERESIS** value for desired temperature limits.
3. Choose the alert threshold type: Select between **OVER**, **UNDER**, or **WINDOW** monitoring.
4. Specify the alert output configuration: Determine your requirements for **POLARITY**, **COMPARATOR/ INTERRUPT**, **FAULT CONDITIONS**, **ARCHITECTURE TYPE**, and **ANALOG/DIGITAL** interfaces
5. Filter the product selection: Use [Table 5-1](#) to find devices that match your criteria.
6. Configure desired settings within the chosen device with the guidance of the datasheet

## 1.2 TMP390 Window Alert Example

The TMP390 is a reliable solution for implementing overtemperature, undertemperature, or window alert configurations. It features both cold and hot trip channels. To adjust the alert thresholds, the resistors connected to the SETA and SETB input pins must be modified. The output is open-drain, meaning a pull-up resistor is required for proper interfacing.

For example, the TMP390 can be configured for window comparison, as illustrated in [Figure 1-2](#). In this setup, overtemperature detection is set to 90°C with 10°C hysteresis, while undertemperature detection is set to -25°C with 10°C hysteresis.

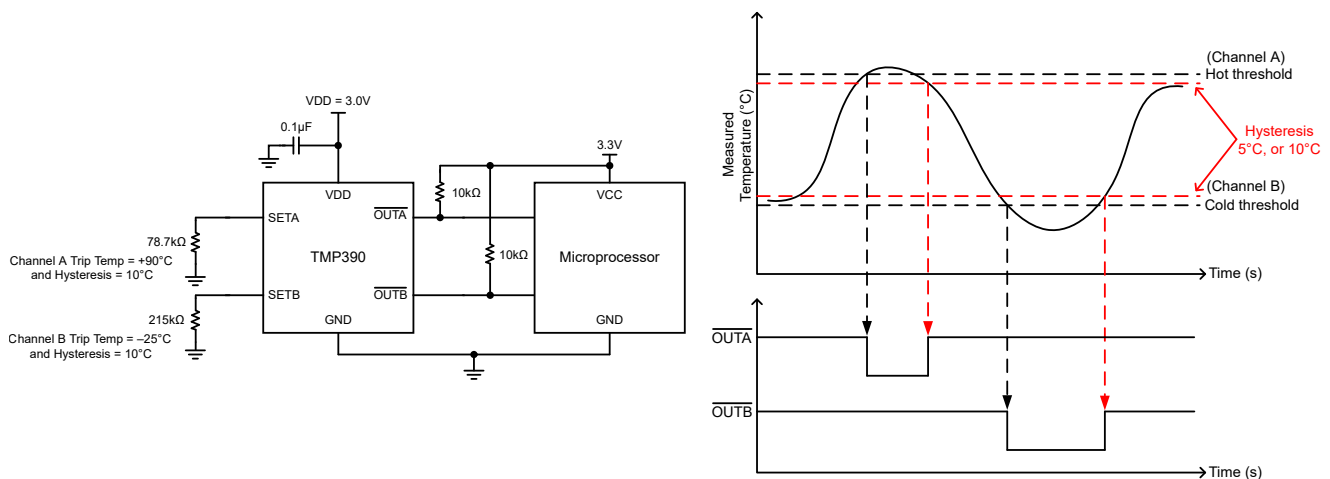


Figure 1-2. TMP390 Window Alert Example

## 1.3 TMP390 Cold Trip Example

Additionally, the TMP390 can be setup exclusively for cold temperature detection. The example below demonstrates how to configure the device for under-temperature (cold trip) operation at 0°C temperature detection.

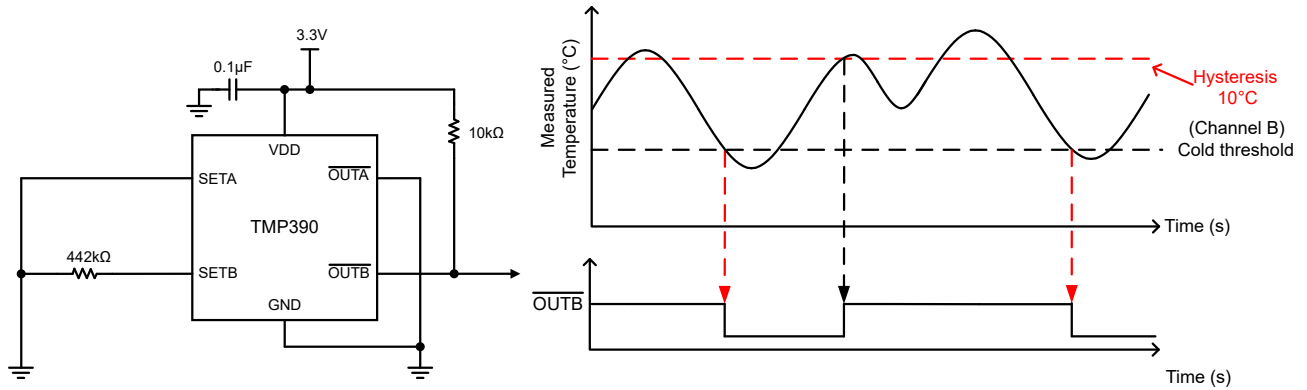


Figure 1-3. TMP390 Cold Trip Example

## 2 Threshold

### 2.1 Hysteresis

Before defining over and under temperature alert threshold, it is important to understand the concept of alert hysteresis and why it is critical in monitoring systems. In real world applications, sensor measurements often fluctuate slightly due to electrical noise, environmental changes, or normal system variation. Hysteresis defines the delta at which the alert must recover. Once the alert limit has been passed, the alert limit will continue to stay on until hysteresis has been met. Without hysteresis, these small fluctuations can cause the alerts to repeatedly trigger and clear when measured value hovers near a threshold. The hysteresis threshold must be selected based on the magnitude of the noise present in the system. As noise amplitude increases, the hysteresis window must also increase to prevent false triggering. A good rule to follow is to set the hysteresis to twice the size of the noise peak to peak amplitude. The reference design [Comparator with Hysteresis Reference Design](#) provides an example in how hysteresis can improve the output signal.

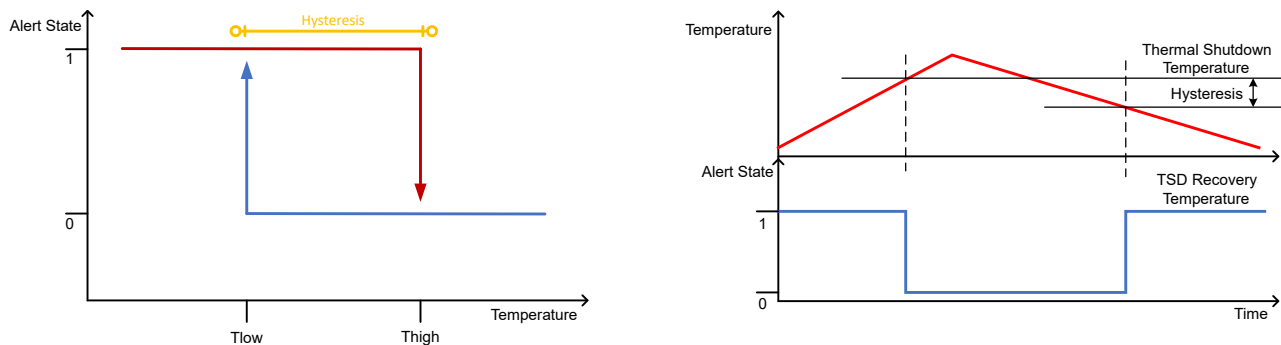


Figure 2-1. Hysteresis for Active Low

There are multiple options at which hysteresis can be defined within the temperature sensor. TI's portfolio contain the following configurations.

- Resistor Set: Resistors are used to set the amount of thermal hysteresis (TMP390)
- Pin Programmable: Pins are used to set the amount of thermal hysteresis (TMP303, TMP302)
- Factory Preset: Hysteresis set at TI factory (LM26LV)
- I2C Register Changable: Write the desired hysteresis into the I2C register (TMP112, TMP119)

## 2.2 Response Time

Evaluating response time ensures that the system reacts within safe operational margins during a thermal event. The ideal condition without response time is shown in Figure 2-2 where an alert signal is turned on once the temperature passes the temperature limit.

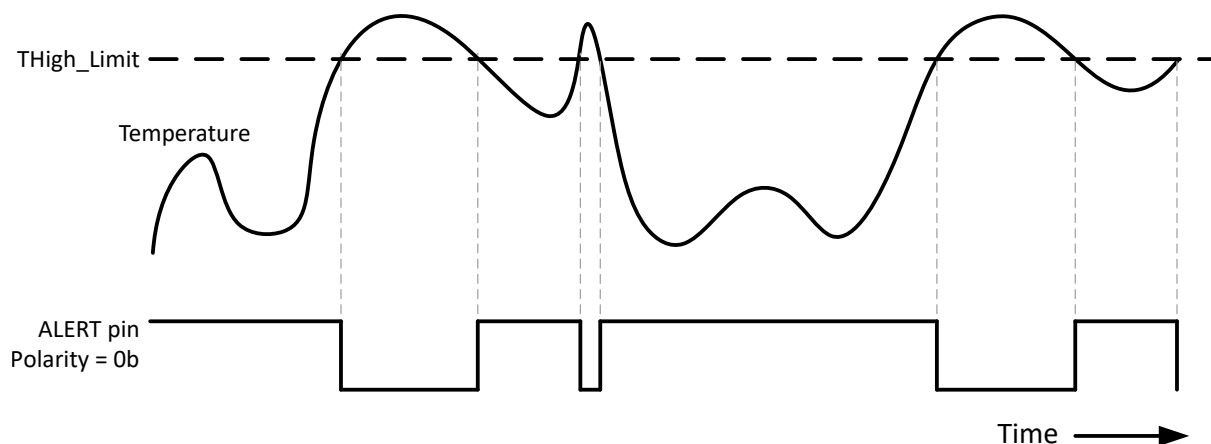


Figure 2-2. Ideal Overtemperature Detection

This is an ideal case. Analog temperature sensors and switches follow the ideal case. For digital temperature sensors the alert output change only takes effect after a full conversion is complete. A conversion refers to the process of measuring the analog temperature and translating it into a digital value that is stored in a register. Since temperature sensors update the temperature register at discrete conversion intervals, the alert response is inherently quantized in time as shown in Figure 2-3. This adds delay to the alert output. The length of delay depends on the configured conversion rate which can be found within the datasheet of the device. System response time must account for this conversion latency when designing protection or monitoring schemes.

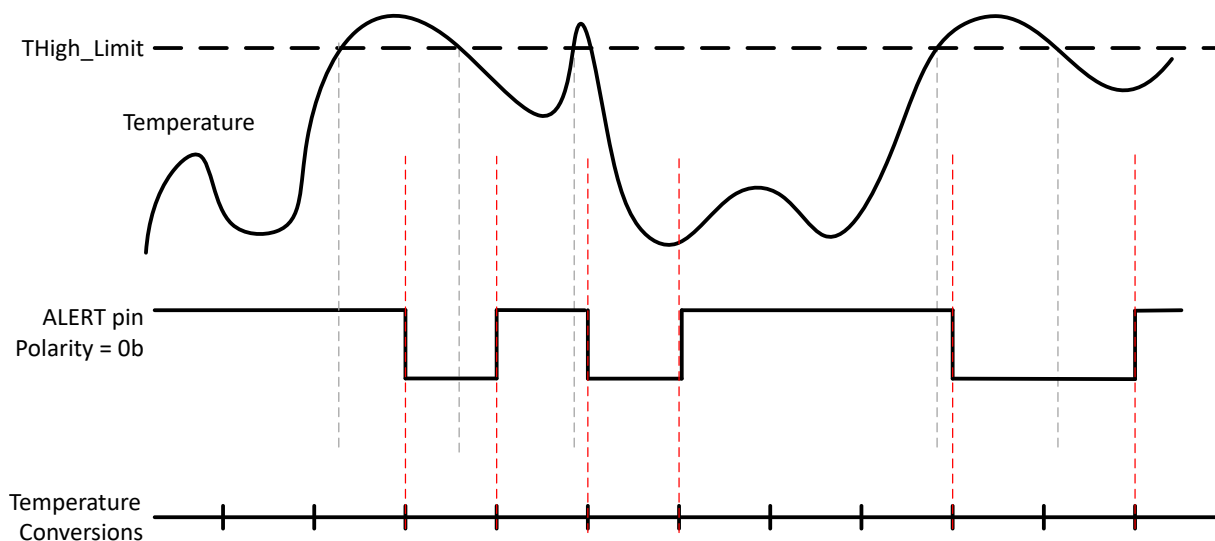


Figure 2-3. Realistic Overtemperature Detection

### 2.3 Overtemperature Threshold

TI has a selection of device that can be configured for only over temperature detection. Figure 2-4 highlights an example of an over temperature signal with proper hysteresis and response time. To optimize performance, many TI temperature sensors also implement a  $T_{Low}$  threshold, or hysteresis, in conjunction with the  $T_{High}$  limit. The  $T_{Low}$  threshold (hysteresis) determines the temperature at which the alert condition is cleared after being triggered by exceeding  $T_{High}$ .  $T_{Low}$  defines the set temperature value the alert should recover.

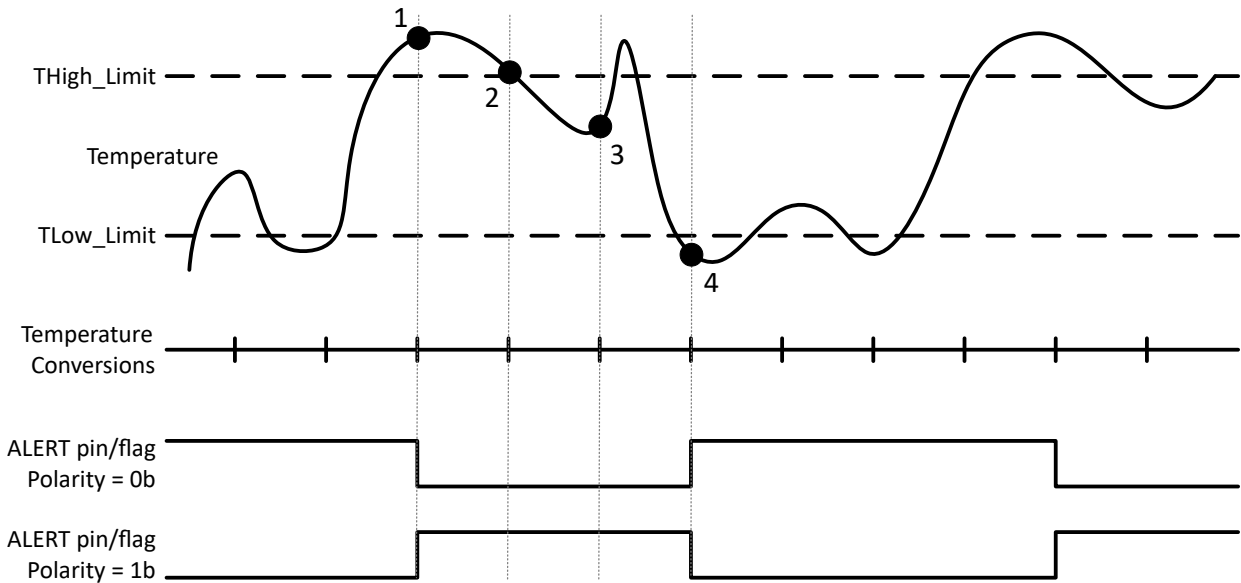


Figure 2-4. Realistic Overtemperature Detection with Hysteresis Recovery

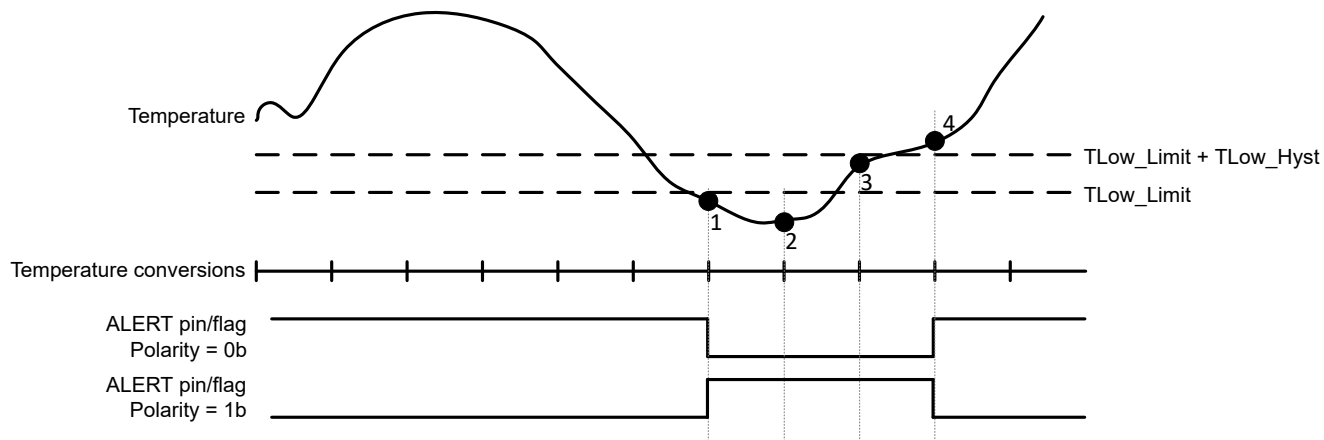
Table 2-1. Stages of the Alert Signal

Location	Action
Point 1	First temperature conversion to detect thermal event above $T_{High}$
Point 2	Still below $T_{High}$
Point 3	Still above $T_{Low}$ Hysteresis, alert will not clear
Point 4	Alert clears when temperature sinks below $T_{High} + \text{Hysteresis}$ ( $T_{Low}$ )

### 2.4 Undertemperature Threshold

In contrast to over temperature detection, TI has a selection of device that can be configured for under temperature detection. These devices monitor when the ambient or system temperature drops below a predefined threshold. Differences in the alert signal are defined below:

1. Trigger Direction: Undertemperature detection activates when the temperature falls below the limit, while over-temperature detection activates when the temperature rises above the limit.
2. Hysteresis Behavior: In undertemperature detection, hysteresis is applied above the threshold so that the alert clears only after the temperature rises past the hysteresis point. In over-temperature detection, hysteresis is applied below the threshold, so the alert clears after the temperature cools sufficiently.



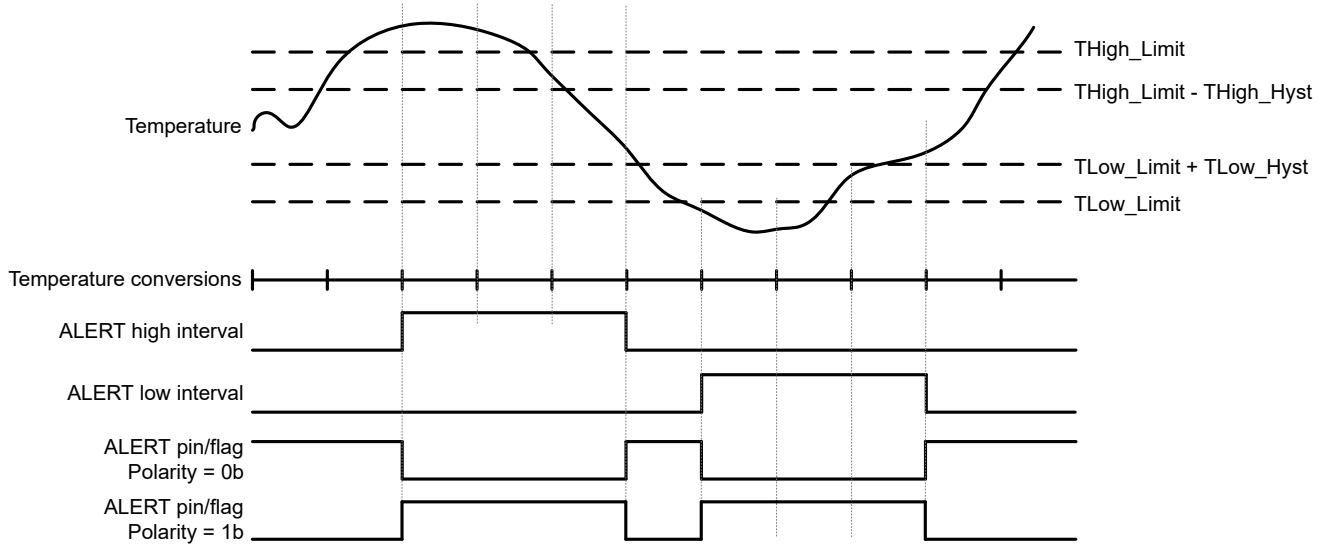
**Figure 2-5. Undertemperature Detection**

**Table 2-2. Stages of the Alert Signal**

Location	Action
Point 1	First temperature conversion to detect thermal event under $T_{Low}$
Point 2	Still below $T_{Low}$
Point 3	Still below $T_{Low}$ Hysteresis, alert will not clear
Point 4	Alert clears when temperature rises above $T_{Low} + \text{Hysteresis}$

## 2.5 Window Monitoring Threshold

In combination, TI has a selection of devices that can collect both over- and undertemperature detection with two temperature limits. Each limit includes an associated hysteresis value to prevent false triggering caused by noise and minor temperature fluctuations near the threshold. Two limits are defined as high and low temperature thresholds. The alert does not recover until the temperature has reached the hysteresis set value.



**Figure 2-6. Over and Undertemperature Detection with Hysteresis Recovery**

### 3 Different Alert Output Types

The three main types of alerts are overtemperature, undertemperature, and window monitoring. There are different ways in which the signal can be displayed but still contain the same functionality. For digital sensors, the settings must be adjusted within the I2C registers to change the desired output. The different output options are highlighted as follows:

- Polarity
- Comparator/ Interrupt Mode
- Fault and Masking Conditions
- Push-Pull and Open Drain
- Digital Output

#### 3.1 Polarity

The polarity can be configured to choose whether the alert signal is active-low or active-high. Switching polarity verifies compatibility with the logic and hardware design of the system. Active Low (default) is where the ALERT pin pulls low when a fault occurs. Active low is preferred for wired-OR interrupt lines and open-drain systems allowing multiple devices to signal "interrupt" without short circuiting or damaging other devices. Active high is when the ALERT pin drives high when a fault occurs. Active high is useful when interfacing directly with logic expecting a high-true interrupt. Polarity is configurable on digital devices. Some analog switches provide both polarity outputs like LM57.

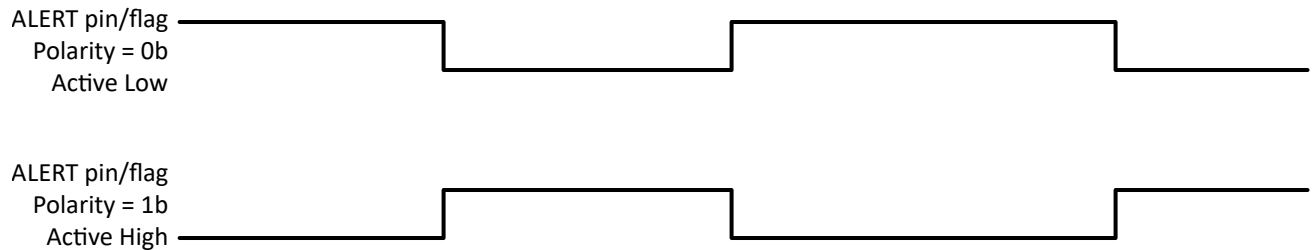


Figure 3-1. Types of Polarity

#### 3.2 Comparator/Interrupt Mode

The alert pin can operate in two modes: Comparator Mode and Interrupt Mode. These define how the ALERT output behaves when temperature crosses programmed thresholds. In comparator mode, the ALERT pin behaves like a live comparator output. Comparator mode is a standalone switch that can drive a fan or system shutdown without software. In interrupt mode, the ALERT pin latches when a fault occurs. The latch is commonly cleared by I<sup>2</sup>C read. Interrupt is intended to save power in the MCU and can be used where event logging of faults is required.

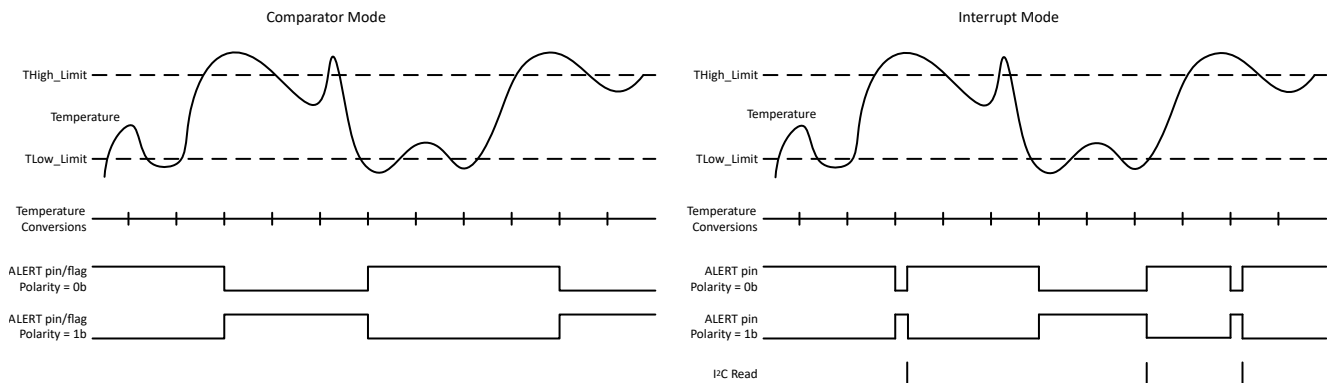


Figure 3-2. Comparator vs Interrupt For Overtemp Alert

**Table 3-1. Comparator vs Interrupt Mode**

Event	Comparator Mode Reaction	Interrupt Mode Reaction
Thermal Event	Triggers once when temperature crosses a threshold	Triggers once when temperature crosses a threshold
Return Within Thermal Limits	Automatically clears once temperature returns to a safe range	Stays asserted even if temperature returns to normal
Alert Reset	No software action required to reset	Requires MCU read to release the alert

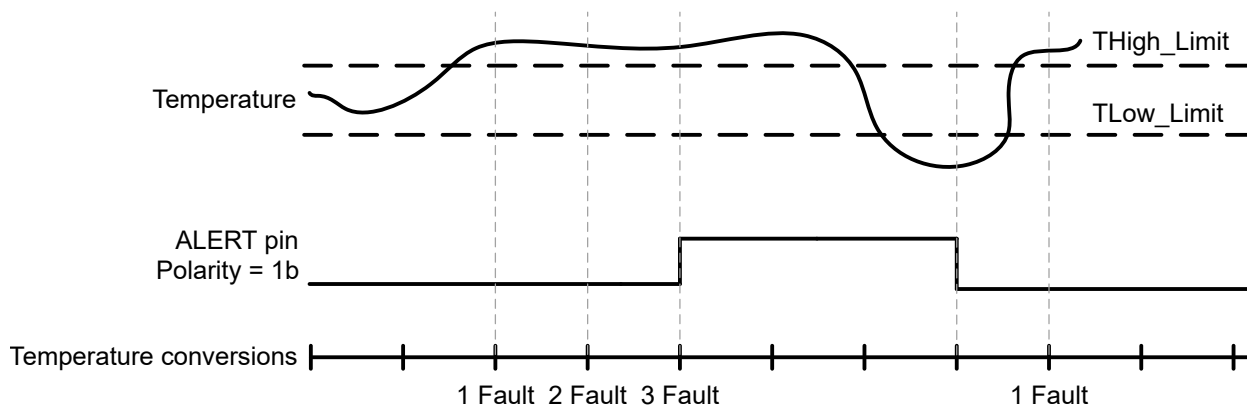
### 3.3 Latching Function

Similar to interrupt mode, certain devices feature a latching function where the alert output remains active once the temperature exceeds specified limits. While interrupt mode is typically used in digital systems requiring an MCU read, latch mode is more common in analog devices. Recovering the alert signal requires either a hard power-on reset or pulling a designated pin low. Devices with this functionality are listed below:

- LM26LV
- LM57

### 3.4 Fault and Masking Conditions

A fault condition exists when the measured temperature exceeds the user-defined limits set in the THIGH and TLOW registers. Adding faults refers to configuring a device so that an alert condition is only triggered after a specified number of consecutive fault events occur, rather than on the first occurrence. Fault conditions can be configured into Alert output through the I2C registers. Some devices have the option to mask out the alert signal. This entails hiding the alert output. Some devices have the mask enabled by default and must be enabled in the device.



**Figure 3-3. Fault Queue 3 Setting Change Output**

### 3.5 Architecture Type (Push-Pull vs Open Drain)

Push pull and Open Drain are two common output configurations that are offered within our temperature portfolio. A push-pull output actively drives a signal both high and low using two gates, allowing for fast switching and strong signal control. In contrast, an open-drain output can only pull the signal low and relies on an external pull-up resistor to bring the signal high. Open drain is useful for shared I2C communication lines, where multiple devices can safely connect.

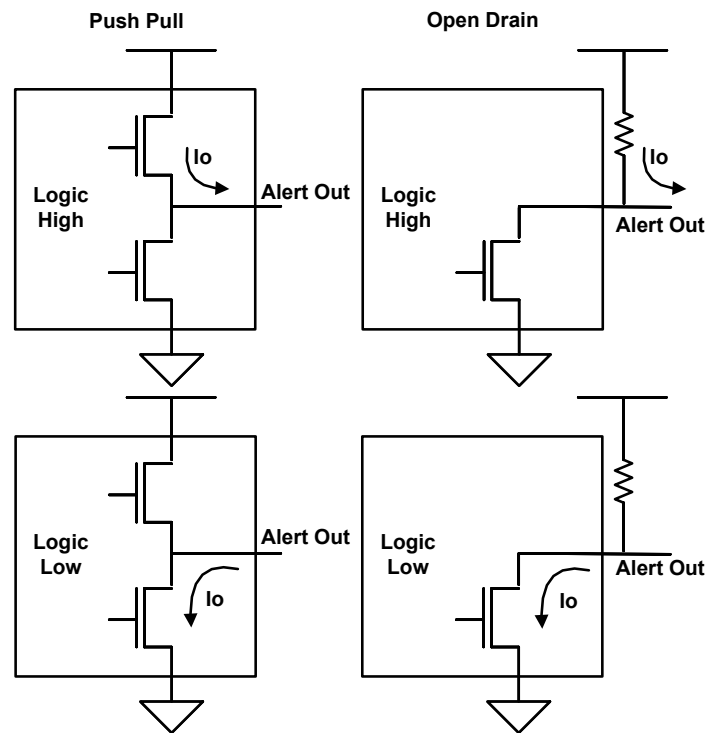


Figure 3-4. Push Pull vs Open Drain Alert Output Configuration

### 3.6 Digital Output

Capturing the binary output signal is an alternative to using the alert pin. Through the I2C registers, the status of the alert pin can be read directly. Without the alert pin, considerations for smaller packages can be made. Risks of only reading the alert status is highlighted below:

- Missed Events: If the controller does not poll frequently enough, short-lived temperature violations can occur and clear before being read
- Increased Bus Traffic: Continuous polling adds load to the I2C bus and can impact performance, especially with multiple devices
- Processor Overhead: The host MCU must actively manage polling instead of reacting to an interrupt

## 4 Switches

An alert output can come within a temperature switch or within an analog or digital temperature sensor. An analog or digital temperature sensor can be configured to be only used as a switch. Temperature switches provide a simple and reliable method for detecting when a temperature threshold is exceeded. The main benefits for selecting a temperature with is highlighted below:

- Autonomous Operation: Functions completely without requiring software or MCU input
- Cost-Efficient Integration: Combines both the temperature sensor and a comparator into a single IC, simplifying system design and reducing overall costs.

Temperature switches monitor temperature and assert an output when a predefined limit is reached, enabling immediate system response such as warnings, shutdown, or cooling activation. TI has three variations of switches depending on how alert limits are defined. Refer to the datasheet for how to choose the desired alert limit as there may be some limitations depending on the device.

- Resistor Set: Resistor Selectable Trip Points
- Pin Programmable: Pin Selectable Trip Points
- Factory Preset: Trip Points Set at TI Factory

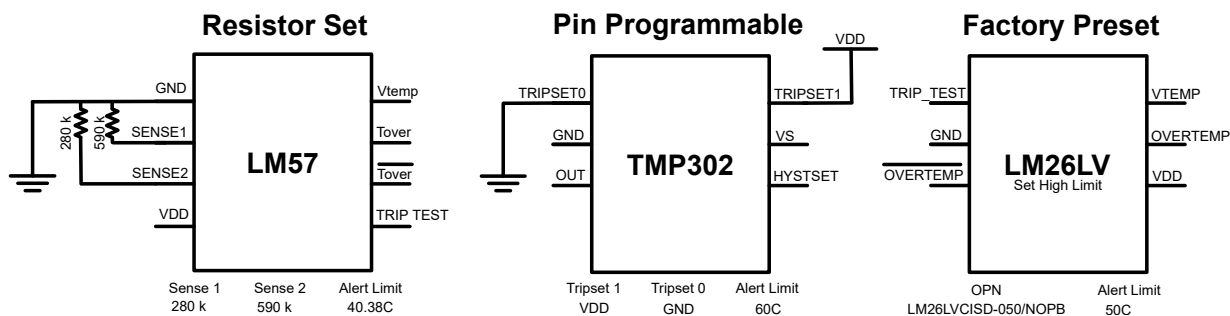


Figure 4-1. Different Types of Switches

Switches can be categorized between analog or digital depending on if they contain an internal ADC for the alert output. Digital devices with an ADC will have a conversion time delay as the output will only display at the end of a conversion. Some digital switches include TMP302 and TMP303.

## 5 Temperature Alert Portfolio

TI temperature sensors provide a broad range of designs for alert functionality. The simplest design is the switch portfolio which contains only the alert output. If there is an interest in temperature measurement with the alert output, there are many output types. There is I2C, SPI, and analog output available. For digital temperature sensors, the conversion must be active for the alert signal to activate. Use the table below to help select the desired sensor with the correct alert settings.

**Table 5-1. Comparison Between Top Selling Devices**

GPN	Under or Overtemperature	Alert Architecture Type	Temperature Output	Power (Inactive Shutdown 25C)	Alert Programmable
<a href="#">TMP115</a>	Under and Over	Open-Drain	Digital I2C	15 nA *Avg Iq @ 1 Hz Duty Cycle = 0.4 uA	I2C adjustable Factory Preset
<a href="#">TMP117</a>	Under and Over	Open-Drain	Digital I2C	0.5 uA *Avg Iq @ 1 Hz Duty Cycle = 5 uA	I2C adjustable Factory Preset, retained after power cycle
<a href="#">TMP112</a>	Over	Open-Drain	Digital I2C	0.35 uA *Avg Iq @ 1 Hz Duty Cycle = 7.5 uA	I2C adjustable Factory Preset
<a href="#">TMP126</a>	Under and Over	Open-Drain	Digital SPI	0.5 uA *Avg Iq @ 1 Hz Duty Cycle = 1.2uA	I2C adjustable Factory Preset
<a href="#">TMP4719</a>	Over	Open-Drain	Digital I2C Remote (2 Channel)	1.5 uA *Avg Iq @ 1s Conversion Time (all channels) = 11 uA	I2C adjustable Factory Preset
<a href="#">TMP4718</a>	Over	Open-Drain	Digital I2C Remote (1 Channel)	1.5 uA *Avg Iq @ 2s Conversion Time (all channels) = 4.5 uA	Resistor Set
<a href="#">LM56</a>	Under and Over	Open-Drain	Analog	230 uA	Resistor Set
<a href="#">LM57</a>	Over	Open-Drain and Push-Pull	Analog	28 uA	Resistor Set
<a href="#">LM26LV</a>	Over	Open-Drain and Push-Pull	Analog	16 uA	Factory Present
<a href="#">LM26</a>	Under and/or Over	Open-Drain	Switch	20 uA	Factory Preset
<a href="#">TMP390</a>	Under and/or Over	Open-Drain	Switch	0.25 uA	Resistor Set
<a href="#">TMP303</a>	Under and Over	Push-Pull	Switch	5 uA	Resistor Set
<a href="#">TMP302</a>	Over	Open-Drain	Switch	15 uA	Pin Programmable
<a href="#">TMP392</a>	Over	Open-Drain	Switch	0.25 uA	Resistor Set

## 6 Summary

These alert configuration output options provide flexibility in how temperature alert conditions are detected and reported to the host system. By adjusting polarity, selecting comparator or interrupt mode, and configuring fault and masking conditions, the ALERT output can be tailored to match the monitoring and interrupt handling requirements of the system. Proper configuration verifies reliable detection of over-temperature, under-temperature, or window violations while minimizing false alerts caused by noise or transient conditions.

## 7 References

- Texas Instruments, [Comparator with Hysteresis Reference Design](#), design guide.

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