# MAX16134:
# Safety Application Note

## Failure-In-Time, Failure Mode Distribution and Pin Failure Mode and Effects Analysis

## JULY 2025

### Contents

# 1 | Overview

The scope of this document is to provide information to support integrating the MAX16134 into functional safety designs. This contains:

- Failure-In-Time (FIT) of the component calculated in accordance with the industry reliability standards
- Failure Mode Distribution of the device (FMD)
- Pin Failure Mode and Effects Analysis (Pin FMEA)

**General Description**

The MAX16134 is a low-voltage, ±1% accurate, triple-voltage µP supervisor that monitor up to 3 system-supply voltages for undervoltage (UV) and overvoltage (OV) faults. It detects undervoltage and overvoltage conditions, triggering a reset output when its corresponding input falls outside the factory-trimmed OV and UV window threshold from ±4% to ±11%, with ±1% resolution and 0.25% or 0.50% hysteresis. The reset outputs are active-low, open-drain.

The MAX16134 is available in a small 8-pin SOT23 package and specified over the temperature range of -40°C to +125°C.

**Table 1-1 Product Description**

| Part Number | Primary Function | System Function |
|---|---|---|
| MAX16134 | Low-voltage, ±1% accurate, triple-voltage µP supervisor | Monitor if a System Supply Voltage is out-of-range (OV/UV) and assert corresponding $\overline{\text{RESET}}$ output |

Figure 1-1 shows the product specific block diagram of MAX16134.

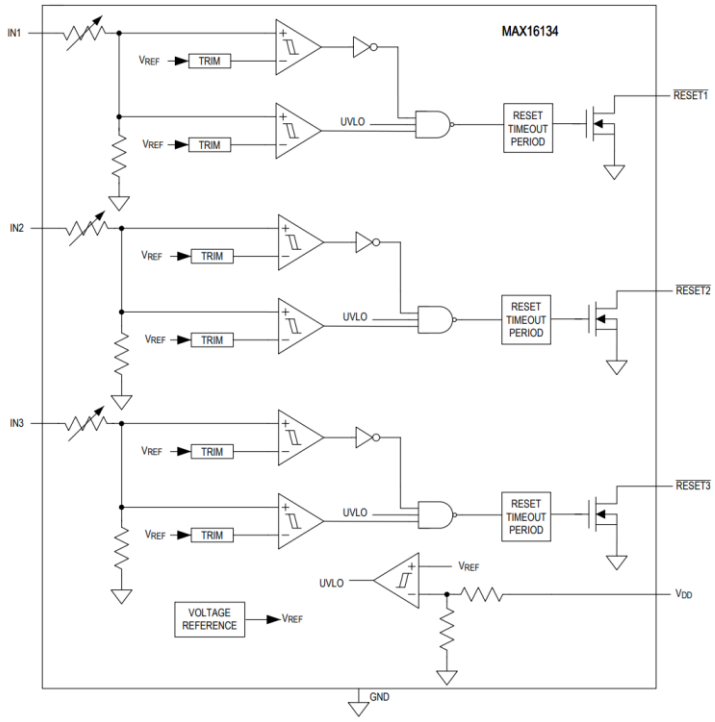


**Figure 1-1 MAX16134 Block Diagram**

The MAX16134 was developed following a quality-managed development process in compliance with the ISO 9001 quality management system standard but was not developed in compliance with the IEC61508 safety standard. The associated certificates are available on Quality Certificates | Analog Devices.

# 2 | Functional Safety Failure-In-Time (FIT)

This section offers specific details on the base functional safety failure-in-time (FIT) for MAX16134, according to SN 29500, IEC 62380 and accelerated testing conditions of HTOL. It also identifies the relevant component category for each standard, allowing customers to compute their own failure rates.

- Table 2-1 provides FIT according to SN 29500
- Table 2-2 provides FIT according to IEC 62380
- Table 2-3 provides FIT according to HTOL

The FIT of MAX16134 based on SN 29500 for a specific industrial mission profile is detailed below:

**Table 2-1 Functional Safety Component FIT According to SN 29500**

| SN 29500 Industrial Mission Profile | FIT (Failures Per $10^9$ Hours) |
|---|---|
| Predicted Component FIT | 50.06 |

- Mission Profile: 20 years constant operation at 55°C temperature
- Operating Voltage (max): 5.5V
- Power Dissipation: 0.165mW
- Theta-JA: 196°C/W

Note 1: For applications requiring a different mission profile, the following information can be used to calculate the base FIT based on SN 29500.

- SN 29500 part: Part 2 Table 5 under ASICs
- Sub-category: CMOS, BiCMOS
- Integration Density: 5k-50k
- Part is sensitive to drift

The FIT of MAX16134 based on IEC 62380 for a specific industrial mission profile is detailed below:

**Table 2-2 Functional Safety Component FIT According to IEC 62380**

| IEC 62380 Industrial Mission Profile | FIT (Failures Per $10^9$ Hours) |
|---|---|
| Total Component FIT | 4.48 |
| Die FIT | 4.34 |
| Package FIT | 0.14 |

Note 2: For applications requiring a different mission profile, the following information can be used to calculate the base FIT based on IEC 62380.

- FIT calculation model: Section 7.3.1, refer to Mathematical Model
- IEC 62380 part and section for die FIT: Table 16, MOS ASIC circuits, Full Custom
- Production year for die FIT: 2019
- Integration Density: 5k-50k
- Climate type: World-wide (Table 8)
- IEC 62380 part and section for package FIT: Table 17b, Two rows connections packages
- Package type: SOT23 8 pins, length: 2.9mm, width: 1.62mm, pitch: 0.65mm
- Technology Structure: MOS BiCMOS (Low Voltage)
- Substrate Material: Epoxy Glass (FR4, G-10)
- EOS FIT assumed: 0 FIT

The FIT of MAX16134 based on accelerated testing conditions of HTOL is detailed below:

**Table 2-3 Functional Safety Component FIT According to HTOL Testing**

| Confidence Level | FIT (Failures Per $10^9$ Hours) |
|---|---|
| 70% | 0.27 |
| 90% | 0.51 |
| 95% | 0.67 |
| 99% | 1.03 |

Note 3: The FIT for various confidence levels were determined through HTOL reliability studies, utilizing the Arrhenius equation for acceleration assuming a chi-square distribution using the following test parameters:

- Sample size: 83,375
- Number of Failures: 0
- Activation Energy: 0.7eV
- Raw Device Hours: 58,309,140
- Accelerated Temperature: 55°C
- Equivalent Accelerated Device Hours: 4,489,980,576

# 3 | Failure Mode Distribution (FMD)

The failure mode distribution includes all relevant failure modes of the product function as defined in the product description.

Table 3-1 shows the failure mode distribution estimation for MAX16134 as derived from the component die area ratio and complexity, and from engineering expertise.

Since some failures had no effect and do not contribute to any failure mode, the total percentage of the Failure Mode Distribution would not add up to 100%. A Correction factor (CF) was applied to the distribution to account for failures with no effect on the system.

**System Function**

- Monitor if a System Supply Voltage is out-of-range (OV/UV) and assert corresponding $\overline{\text{RESET}}$ output.

**Table 3-1 Failure Mode Distribution (CF = 1.23)**

| Failure Modes | Failure Mode Distribution |
|---|---|
| RESET1 always asserted | 15% |
| RESET1 never asserts | 15% |
| RESET1 asserts early | 3% |
| RESET1 asserts late | 1% |
| RESET2 always asserted | 15% |
| RESET2 never asserts | 14% |
| RESET2 asserts early | 3% |
| RESET2 asserts late | 1% |
| RESET3 always asserted | 15% |
| RESET3 never asserts | 14% |
| RESET3 asserts early | 3% |
| RESET3 asserts late | 1% |

# 4 | Pin Failure Mode and Effects Analysis (Pin FMEA)

This section presents the Pin Failure Mode and Effects Analysis (Pin FMEA) for MAX16134. The failure modes discussed in this section encompass the common pin-by-pin failure scenarios:

- Pin short-circuited to supply (see Table 4-1)
- Pin short-circuited to GND (see Table 4-2)
- Pin open-circuited (see Table 4-3)
- Pin short-circuited to adjacent pins (see Table 4-4)

Figure 4-1 illustrates the pin diagram for MAX16134. Refer to the product datasheet for a detailed description of each pin's function.

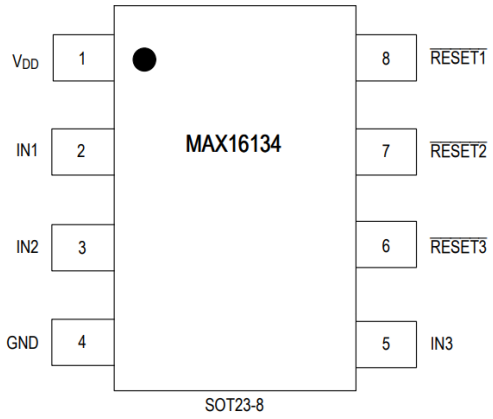


**Figure 4-1. MAX16134 Pin Diagram**

Below are the usage assumptions and device configuration considered for the Pin FMEA, based on the Typical Application Circuit, unless otherwise noted:

- The $\overline{\text{RESET1}}$, $\overline{\text{RESET2}}$, and $\overline{\text{RESET3}}$ pins are active-low reset output available in open-drain configuration.
- The $\overline{\text{RESET1}}$, $\overline{\text{RESET2}}$, and $\overline{\text{RESET3}}$ pins are connected to a 10kΩ pull-up resistor.
- The operating voltage range (VDD) is from 1.71V to 5.5V, and the operating temperature range ($T_A$=$T_J$) is from -40°C to +125°C.
- Typical values are measured at VDD = 5V, and $T_A$ = +25°C.

**Table 4-1 Pin FMEA for MAX16134 Pins Short-Circuited to Supply**

| Pin no. | Pin Name | Effect of Failure Mode |
|---|---|---|
| 1 | VDD | No effect |
| 2 | IN1 | VDD>OV,th: Always OV on IN1. $\overline{\text{RESET1}}$ always low<br>VDD<UV,th: Always UV on IN1. $\overline{\text{RESET1}}$ always low<br>VDD within IN1 range: No effect |
| 3 | IN2 | VDD>OV,th: Always OV on IN1. $\overline{\text{RESET2}}$ always low<br>VDD<UV,th: Always UV on IN1. $\overline{\text{RESET2}}$ always low<br>VDD within IN2 range: No effect |
| 4 | GND | Part not functional |
| 5 | IN3 | VDD>OV,th: Always OV on IN1. $\overline{\text{RESET3}}$ always low<br>VDD<UV,th: Always UV on IN1. $\overline{\text{RESET3}}$ always low<br>VDD within IN3 range: No effect |
| 6 | $\overline{\text{RESET3}}$ | $\overline{\text{RESET3}}$ always high |
| 7 | $\overline{\text{RESET2}}$ | $\overline{\text{RESET2}}$ always high |
| 8 | $\overline{\text{RESET1}}$ | $\overline{\text{RESET1}}$ always high |

**Table 4-2 Pin FMEA for MAX16134 Pins Short-Circuited to GND**

| Pin no. | Pin Name | Effect of Failure Mode |
|---|---|---|
| 1 | VDD | Part not functional |
| 2 | IN1 | Always UV on IN1. $\overline{\text{RESET1}}$ always low |
| 3 | IN2 | Always UV on IN2. $\overline{\text{RESET2}}$ always low |
| 4 | GND | No effect |
| 5 | IN3 | Always UV on IN3. $\overline{\text{RESET3}}$ always low |
| 6 | $\overline{\text{RESET3}}$ | $\overline{\text{RESET3}}$ always low |
| 7 | $\overline{\text{RESET2}}$ | $\overline{\text{RESET2}}$ always low |
| 8 | $\overline{\text{RESET1}}$ | $\overline{\text{RESET1}}$ always low |

**Table 4-3 Pin FMEA for MAX16134 Pins Open-Circuited**

| Pin no. | Pin Name | Effect of Failure Mode |
|---|---|---|
| 1 | VDD | Part has no Power. Part not functional |
| 2 | IN1 | Always UV on IN1. $\overline{\text{RESET1}}$ always low |
| 3 | IN2 | Always UV on IN2. $\overline{\text{RESET2}}$ always low |
| 4 | GND | Part not functional |
| 5 | IN3 | Always UV on IN3. $\overline{\text{RESET3}}$ always low |
| 6 | $\overline{\text{RESET3}}$ | Unreliable $\overline{\text{RESET3}}$ |
| 7 | $\overline{\text{RESET2}}$ | Unreliable $\overline{\text{RESET2}}$ |
| 8 | $\overline{\text{RESET1}}$ | Unreliable $\overline{\text{RESET1}}$ |

**Table 4-4 Pin FMEA for MAX16134 Pins Short-Circuited to Adjacent Pins**

| Pin no. | Pin Name | Shorted to | Effect of Failure Mode |
|---|---|---|---|
| 1 | VDD | IN1 | VDD>OV,th: Always OV on IN1. $\overline{\text{RESET1}}$ always low<br>VDD<UV,th: Always UV on IN1. $\overline{\text{RESET1}}$ always low<br>VDD within IN1 range: No effect |
| 2 | IN1 | IN2 | IN2 may trigger $\overline{\text{RESET1}}$ depending on IN1 thresholds (or IN1 triggers RESET2). Unreliable $\overline{\text{RESET1/2}}$ output |
| 3 | IN2 | GND | Always UV on IN2. $\overline{\text{RESET2}}$ always low |
| 4 | GND | IN3 | Always UV on IN3. $\overline{\text{RESET3}}$ always low |
| 5 | IN3 | $\overline{\text{RESET3}}$ | Unreliable $\overline{\text{RESET3}}$ |
| 6 | $\overline{\text{RESET3}}$ | $\overline{\text{RESET2}}$ | $\overline{\text{RESET2}}$, $\overline{\text{RESET3}}$ or-ing output |
| 7 | $\overline{\text{RESET2}}$ | $\overline{\text{RESET1}}$ | $\overline{\text{RESET2}}$, $\overline{\text{RESET1}}$ or-ing output |
| 8 | $\overline{\text{RESET1}}$ | VDD | $\overline{\text{RESET1}}$ always high |

# 5 | Revision History

| Revision | Revision Date | Description |
|---|---|---|
| A | September 2024 | Initial Release |
| B | July 2025 | Updated *Overview* and *Functional Safety Failure-In-Time (FIT).*<br>Corrected typographical errors and Notes. |

# IMPORTANT NOTES AND DISCLAIMER

PLEASE BE AWARE THAT THE PRODUCT IN QUESTION HAS NOT BEEN DEVELOPED IN ACORDANCE WITH INDUSTRIAL SAFETY STANDARDS AND IS NOT RECOMMENDED FOR SUCH APPLICATIONS AS PER THE SPECIFIC DATA SHEET. THIS REPORT IS INTENDED SOLELY TO PROVIDE THE CUSTOMER WITH DETAILED INFORMATION ON FAILURE MODES AND THEIR DISTRIBUTION ACCORDING TO IEC61508, RELATED TO THE POTENTIAL USE OF QUALITY-MANAGED PARTS FOR SPECIFIC HARDWARE EVALUATION CLASS AS DESCRIBED IN THIS STANDARD.

ANALOG DEVICES AIMS TO ASSIST CUSTOMERS IN DESIGNING AND CREATING THEIR OWN END-PRODUCT SOLUTION THAT COMPLY WITH RELEVANT FUNCTIONAL SAFETY STANDARDS AND REQUIREMENTS. THEREFORE, ANALOG DEVICES DOES NOT GUARANTEE SIL COMPLIANCE AT THE SYSTEM LEVEL. ANALOG DEVICES WILL NOT BE RESPONSIBLE FOR ANY CLAIMS OR DAMAGES ARISING FROM THE CUSTOMER'S USE OF AN ANALOG DEVICES PRODUCT IN LIFE SUPPORT, LIFE-CRITICAL, OR SAFETY-CRITICAL SYSTEMS, EQUIPMENT OR APPLICATIONS. CUSTOMERS WILL INDEMNIFY, DEFEND AND HOLD ANALOG DEVICES HARMLESS FROM ANY CLAIMS, DAMAGES, LOSSES, COSTS, EXPENSES, AND LIABILITIES RESULTING FROM THE USE OF ANY ANALOG DEVICES PRODUCT IN SUCH SYSTEMS, EQUIPMENT, OR APPLICATIONS. ANALOG DEVICES DOES NOT WARRANT THE ACCURACY OR COMPLETENESS OF THIS DOCUMENTATION AND WILL NOT BE LIABLE FOR ITS CONTENT.

www.analog.com



AHEAD OF WHAT'S POSSIBLE™