MAX16134:
Safety Application Note

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

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1 | Overview

The scope of this document is to provide a report on MAX16134 to support in functional safety designs. This contains:

- Failure-In-Time (FIT) rates 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.

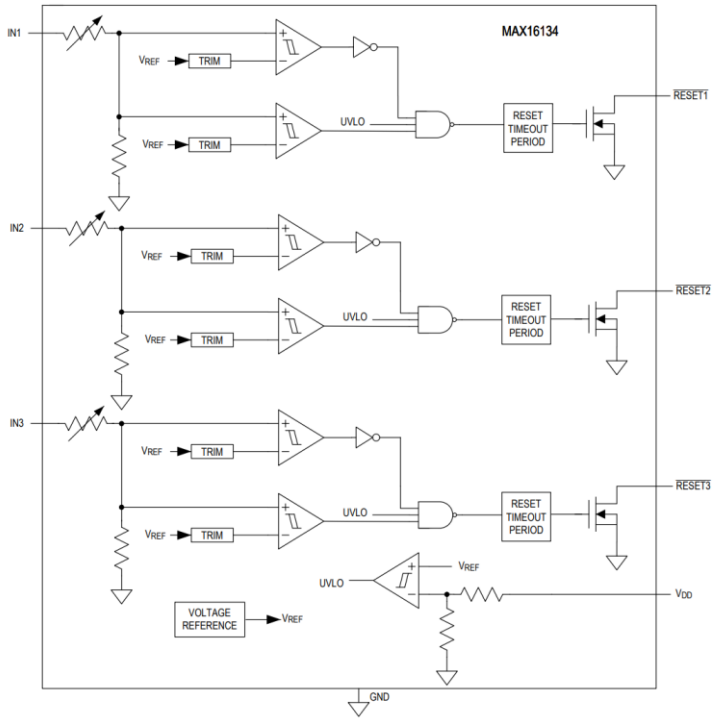

Figure 1-1 MAX16134 Block Diagram

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

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

This section offers specific details on the base functional safety failure-in-time (FIT) rates for MAX16134, according to SN29500, 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 rates according to SN29500
- Table 2-2 provides FIT rates according to IEC 62380
- Table 2-3 provides FIT rates according to HTOL

The FIT rates of MAX16134 based on SN29500 for a specific industrial mission profile is detailed below:

Table 2-1 Functional Safety Component FIT Rate According to SN29500

SN29500 Industrial Mission Profile	FIT (Failures Per 10^9 Hours)
Predicted Component FIT Rate	50.06

- Mission Profile: 20 years constant operation at 55°C temperature
- Climate type: World-wide (Table 8)
- Operating Voltage (max): 5.5V
- Power Dissipation: 0.165mW
- Theta-JA: 196°C/W
- Substrate Material: FR4
- EOS FIT rate assumed: 0 FIT
- Part is sensitive to drift

Note 1: For applications requiring a different mission profile, the following information can be used to calculate the base FIT rate based on SN29500.

- SN29500 part and section: Part 2/Section 5 and ASICs
- Sub-category: CMOS, BiCMOS
- Integration Density: 5k-50k

The FIT rates of MAX16134 based on IEC62380 for a specific industrial mission profile is detailed below:

Table 2-2 Functional Safety Component FIT Rates According to IEC62380

IEC62380 Industrial Mission Profile	FIT (Failures Per 10^9 Hours)
Total Component FIT Rate	4.48
Die FIT Rate	4.34
Package FIT Rate	0.14

Note 2: For applications requiring a different mission profile, the following information can be used to calculate the base FIT rate based on IEC62380.

- FIT rate calculation model: Section 7.3.1, refer to Mathematical Model
- IEC62380 part and section for die FIT rate: Table 16, MOS ASIC circuits, Full Custom
- Production year for die FIT rate: 2019
- Integration Density: 5k-50k
- IEC62380 part and section for package FIT rate: Table 17b, Two rows connections packages
- Package type: SOT23 8 pins, length: 2.9mm, width: 1.62mm, pitch: 0.65mm
- Interface device (EOS relevant): No

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

Table 2-3 Functional Safety Component FIT Rates 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 rates 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: 58,909,140
- 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.

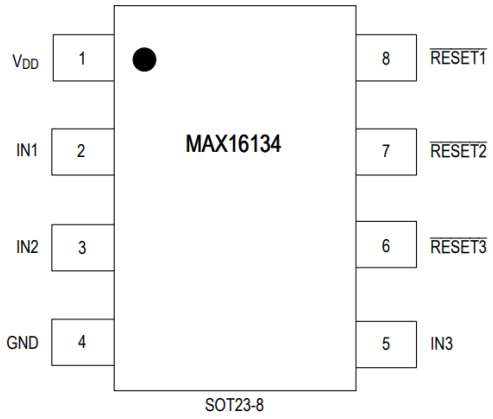

Figure 4-1. MAX16134 Pin Diagram

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 VDD<UV,th: Always UV on IN1. $\overline{\text{RESET1}}$ always low VDD within IN1 range: No effect
3	IN2	VDD>OV,th: Always OV on IN1. $\overline{\text{RESET2}}$ always low VDD<UV,th: Always UV on IN1. $\overline{\text{RESET2}}$ always low 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 VDD<UV,th: Always UV on IN1. $\overline{\text{RESET3}}$ always low 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 VDD<UV,th: Always UV on IN1. $\overline{\text{RESET1}}$ always low 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

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.

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