*Functional Safety Information*

# *AFE881H1*
# *Functional Safety FIT Rate, FMD, and Pin FMA*

## Table of Contents



## Trademarks

# 1 Overview

This document contains information for the AFE881H1 (QFN package) to aid in a functional safety system design. Information provided are:

- Functional safety failure in time (FIT) rates of the semiconductor component estimated by the application of industry reliability standards
- Component failure modes and their distribution (FMD) based on the primary function of the device
- Pin failure mode analysis (pin FMA)

Figure 1-1 shows the device functional block diagram for reference.

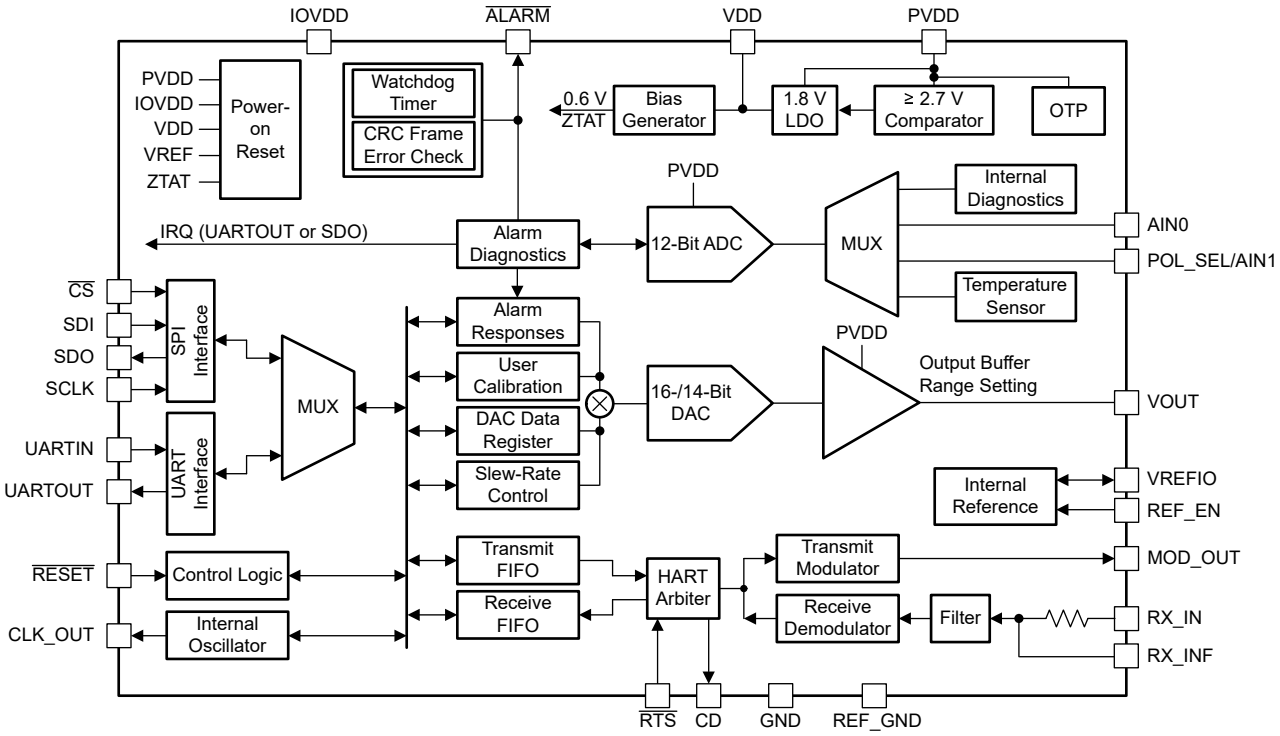


**Figure 1-1. Functional Block Diagram**

The AFE881H1 was developed using a quality-managed development process, but was not developed in accordance with the IEC 61508 or ISO 26262 standards.

## 2 Functional Safety Failure In Time (FIT) Rates

This section provides functional safety failure in time (FIT) rates for the AFE881H1 based on two different industry-wide used reliability standards:

- Table 2-1 provides FIT rates based on IEC TR 62380 / ISO 26262 part 11
- Table 2-2 provides FIT rates based on the Siemens Norm SN 29500-2

**Table 2-1. Component Failure Rates per IEC TR 62380 / ISO 26262 Part 11**

| FIT IEC TR 62380 / ISO 26262 | FIT (Failures Per $10^9$ Hours) |
|---|---|
| Total component FIT rate | 13 |
| Die FIT rate | 2 |
| Package FIT rate | 11 |

The failure rate and mission profile information in Table 2-1 comes from the reliability data handbook IEC TR 62380 / ISO 26262 part 11:

- Mission profile: Motor control from table 11
- Power dissipation: 1 mW
- Climate type: World-wide table 8
- Package factor (lambda 3): Table 17b
- Substrate material: FR4
- EOS FIT rate assumed: 0 FIT

**Table 2-2. Component Failure Rates per Siemens Norm SN 29500-2**

| Table | Category | Reference FIT Rate | Reference Virtual $T_J$ |
|---|---|---|---|
| 5 | CMOS, BICMOS<br>Digital, analog, or mixed | 60 FIT | 70°C |

The reference FIT rate and reference virtual $T_J$ (junction temperature) in Table 2-2 come from the Siemens Norm SN 29500-2 tables 1 through 5. Failure rates under operating conditions are calculated from the reference failure rate and virtual junction temperature using conversion information in SN 29500-2 section 4.

# 3 Failure Mode Distribution (FMD)

The failure mode distribution estimation for the AFE881H1 in Table 3-1 comes from the combination of common failure modes listed in standards such as IEC 61508 and ISO 26262, the ratio of sub-circuit function size and complexity, and from best engineering judgment.

The failure modes listed in this section reflect random failure events and do not include failures resulting from misuse or overstress.

**Table 3-1. Die Failure Modes and Distribution**

| Die Failure Modes | Failure Mode Distribution (%) |
|---|---|
| DAC output incorrect or not functional | 36 |
| Digital communication error | 19 |
| HART communication not functional | 19 |
| Diagnostic ADC measurement incorrect or not functional | 16 |
| Reset at power-on and internal supplies not functional | 7 |
| Internal oscillator not functional | 3 |

# 4 Pin Failure Mode Analysis (Pin FMA)

This section provides a failure mode analysis (FMA) for the pins of the AFE881H1. The failure modes covered in this document include the typical pin-by-pin failure scenarios:

- Pin short-circuited to ground (see Table 4-2)
- Pin open-circuited (see Table 4-3)
- Pin short-circuited to an adjacent pin (see Table 4-4)
- Pin short-circuited to supply (see Table 4-5)

Table 4-2 through Table 4-5 also indicate how these pin conditions can affect the device as per the failure effects classification in Table 4-1.

**Table 4-1. TI Classification of Failure Effects**

| Class | Failure Effects |
|---|---|
| A | Potential device damage that affects functionality. |
| B | No device damage, but loss of functionality. |
| C | No device damage, but performance degradation. |
| D | No device damage, no impact to functionality or performance. |

Figure 4-1 shows the AFE881H1 pin diagram. For a detailed description of the device pins, see the *Pin Configuration and Functions* section in the AFE881H1 data sheet.

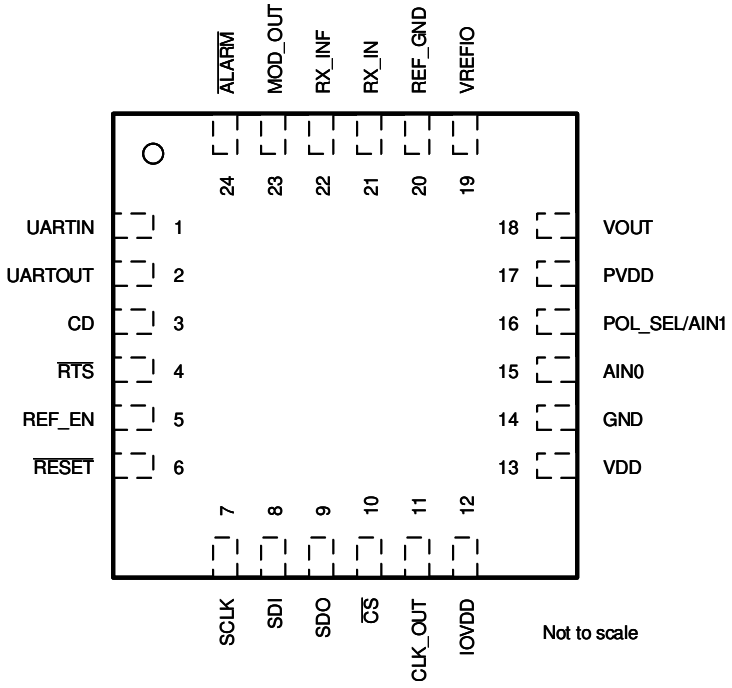


**Figure 4-1. Pin Diagram**

Following are the assumptions of use and the device configuration assumed for the pin FMA in this section:

- At least two SPI devices are present on the SPI bus.
- VDD and IOVDD use the same supply voltage.
- 'Short circuit to GND' means short to GND = REF_GND.
- 'Short circuit to Power' means short to PVDD = IOVDD = 3.3 V.

**Table 4-2. Pin FMA for Device Pins Short-Circuited to Ground**

| Pin Name | Pin No. | Description of Potential Failure Effects | Failure Effect Class |
|---|---|---|---|
| UARTIN | 1 | UARTIN forced low. No UART communication to the device. SPI communication is possible. | B |
| UARTOUT | 2 | UARTOUT forced low. No UART communication from the device. SPI communication is possible. An increase in supply current can be observed. Device damage is possible if UARTOUT is connected to ground for an extended period of time. | A |
| CD | 3 | CD pin forced low. Shorting pin to ground can increase supply current, and carrier detection is not functional. Device damage is possible if the pin is connected to ground for an extended period of time. HART communication is not functional. | A |
| $\overline{\text{RTS}}$ | 4 | $\overline{\text{RTS}}$ pin forced low. HART communication is not functional. | B |
| REF_EN | 5 | REF_EN forced low. The internal reference is not enabled, and the device does not have the proper output if the internal reference is used. The device operates normally if an external reference is used. | B |
| $\overline{\text{RESET}}$ | 6 | $\overline{\text{RESET}}$ is forced low. The device is held in reset and is not functional. | B |
| SCLK | 7 | SCLK forced low. No SPI communication with the device. UART communication is possible. | B |
| SDI | 8 | SDI forced low. No SPI communication to the device. UART communication is possible. | B |
| SDO | 9 | SDO forced low. No SPI communication from the device. UART communication is possible. An increase in supply current can be observed. Device damage is possible if SDO is connected to ground for an extended period of time. | A |
| $\overline{\text{CS}}$ | 10 | $\overline{\text{CS}}$ forced low. No SPI communication with the device. UART communication is possible. | B |
| CLK_OUT | 11 | CLK_OUT forced low; internal oscillator disabled. If internal oscillator is disabled, CLK_OUT pin appears as Hi-Z, and the device operates normally. | D |
| | | CLK_OUT forced low; internal oscillator enabled. Increase in supply current when CLK_OUT is enabled. Device damage is possible if CLK_OUT is enabled for an extended period of time. | A |
| IOVDD | 12 | IOVDD supply grounded. The device is not powered and not functional. Verify that the absolute maximum ratings for all pins of the device are met; otherwise, device damage is possible. | A |
| VDD | 13 | VDD supply grounded. The device is not functional. The internal LDO is shorted to ground. Shorting pin to ground can increase supply current. Device damage is possible if the pin is connected to ground for an extended period of time. | A |
| GND | 14 | No effect. Normal operation. | D |
| AIN0 | 15 | AIN0 forced low. Conversion results for ADC0 are incorrect. | B |
| POL_SEL/ AIN1 | 16 | POL_SEL/AIN1 forced low; ADC SPECIAL_CFG.AIN1_ENB set to 1. Conversion results for AIN1 are incorrect. | B |
| | | POL_SEL/AIN1 forced low; ADC SPECIAL_CFG.AIN1_ENB set to 0. POL_SEL can be set to the wrong polarity depending on the selected DAC VOUT alarm voltage (ALMV_POL). | B |
| PVDD | 17 | PVDD supply grounded. The device is not powered and not functional. Verify that the absolute maximum ratings for all pins of the device are met; otherwise, device damage is possible. | A |
| VOUT | 18 | VOUT forced low. DAC output is shorted and not functional. Shorting the pin to ground can increase supply current. | B |
| VREFIO | 19 | VREFIO forced low; internal reference disabled, external reference connected. The DAC output is incorrect and not functional. | B |
| | | VREFIO forced low; internal reference enabled. Shorting the pin to ground can increase supply current. Device damage is possible if the internal reference is enabled and VREFIO is connected to ground for an extended period of time. | A |
| REF_GND | 20 | No effect. Normal operation. | D |
| RX_IN | 21 | RX_IN pin forced low. HART communication can be disrupted or not functional. | B |
| RX_INF | 22 | RX_INF pin forced low. HART communication can be disrupted or not functional. | B |
| MOD_OUT | 23 | MOD_OUT pin forced low. Shorting the pin to ground can increase supply current. HART communication is not functional. Device damage is possible if pin is connected to GND for an extended period of time. | A |
| $\overline{\text{ALARM}}$ | 24 | $\overline{\text{ALARM}}$ pin forced low. Pin is not functional. | B |

**Table 4-3. Pin FMA for Device Pins Open-Circuited**

| Pin Name | Pin No. | Description of Potential Failure Effects | Failure Effect Class |
|---|---|---|---|
| UARTIN | 1 | UARTIN input is undetermined. No UART communication to the device. SPI communication is possible. | B |
| UARTOUT | 2 | UARTOUT output is undetermined. No UART communication from the device. SPI communication is possible. | B |
| CD | 3 | CD output is undetermined. HART communication is not functional. | B |
| $\overline{\text{RTS}}$ | 4 | $\overline{\text{RTS}}$ output undetermined. HART communication is not functional. | B |
| REF_EN | 5 | REF_EN input is undetermined; external reference not connected. Device functionality is undetermined. The reference can operate normally or be disabled. | B |
| | | REF_EN input is undetermined; external reference connected. Device damage is possible if an external reference drives VREFIO. | A |
| $\overline{\text{RESET}}$ | 6 | $\overline{\text{RESET}}$ input is undetermined. Device functionality is undetermined. The device can operate normally or be held in reset. | B |
| SCLK | 7 | SCLK input is undetermined. No SPI communication with the device. UART communication is possible. | B |
| SDI | 8 | SDI input is undetermined. No SPI communication to the device. UART communication is possible. | B |
| SDO | 9 | SDO output is undetermined. No SPI communication from the device. UART communication is possible. | B |
| $\overline{\text{CS}}$ | 10 | $\overline{\text{CS}}$ input is undetermined. No SPI communication with the device. UART communication is possible. | B |
| CLK_OUT | 11 | CLK_OUT is unconnected. The device operates normally but the oscillator clock is not available. | B |
| IOVDD | 12 | IOVDD supply is unconnected. The device is not powered and not functional if all external digital pins are held low. The device can power up through internal ESD diodes to IOVDD if voltages greater than the power-on reset threshold of the device are present on any of the digital pins. Device functionality is undetermined. | B |
| VDD | 13 | Output of LDO is unconnected. Without connection to capacitor, output can oscillate and device functionality is undetermined. | B |
| GND | 14 | Device functionality is undetermined. The device can be unpowered or connected to ground internally to be powered. | B |
| AIN0 | 15 | AIN0 input is undetermined. The conversion results of ADC0 are undetermined. | B |
| POL_SEL/ AIN1 | 16 | ADC SPECIAL_CFG.AIN1_ENB set to 1. The conversion results of AIN1 are undetermined. | B |
| | | ADC SPECIAL_CFG.AIN1_ENB set to 0. The POL_SEL input is undetermined. POL_SEL can be set to the wrong polarity depending on the selected DAC VOUT alarm voltage (ALMV_POL). | B |
| PVDD | 17 | PVDD supply is unconnected. The device is not powered and not functional if all external pins are held low. The device can power up through internal ESD diodes to PVDD if voltages greater than the power-on reset threshold of the device are present on any of the digital pins. Device functionality is undetermined. | B |
| VOUT | 18 | VOUT is unconnected. DAC output floating. | B |
| VREFIO | 19 | VREFIO is unconnected. With internal reference enabled, output can oscillate without load capacitance. | B |
| | | VREFIO is unconnected. When using an external reference, the DAC reference is disconnected. The DAC output is incorrect. | B |
| REF_GND | 20 | REF_GND is unconnected. The device reference does not set to proper voltage. The DAC output is incorrect. | B |
| RX_IN | 21 | If RX_IN is the intended HART input, then the RX_IN output is undetermined. HART communication is not functional. | B |
| | | If RX_INF is the intended HART input, then RX_IN is left open-circuited. The device operates normally. | D |
| RX_INF | 22 | If RX_IN is the intended HART input, then the required 680-pF capacitor for RX_INF to GND is unconnected. HART communication is not functional. | B |
| | | If RX_INF is the intended HART input, then RX_INF is unconnected. HART communication is not functional. | B |
| MOD_OUT | 23 | MOD_OUT is unconnected. HART communication is not functional. | B |
| $\overline{\text{ALARM}}$ | 24 | $\overline{\text{ALARM}}$ is unconnected. No $\overline{\text{ALARM}}$ communication back to controller is possible. | B |

**Table 4-4. Pin FMA for Device Pins Short-Circuited to Adjacent Pin**

| Pin Name | Pin No. | Shorted to | Description of Potential Failure Effects | Failure Effect Class |
|---|---|---|---|---|
| UARTIN | 1 | UARTOUT | UART communication contention. SPI communication is possible. An increase in supply current can be observed if the driver of UARTIN drives UARTOUT. Device damage is possible if connected for an extended period of time. | A |
| UARTOUT | 2 | CD | Contention between UARTOUT pin and CD pin. HART and UART communication can be disrupted or not functional. Device damage is possible if connected for an extended period of time. | A |
| CD | 3 | $\overline{RTS}$ | Contention between CD pin and $\overline{RTS}$ pin. HART communication can be disrupted or not functional. Device damage is possible if connected for an extended period of time. | A |
| $\overline{RTS}$ | 4 | REF_EN | Contention between $\overline{RTS}$ pin and REF_EN pin. HART communication can be disrupted or not functional. DAC output can be incorrect. | B |
| REF_EN | 5 | $\overline{RESET}$ | REF_EN undetermined; internal reference intended. The device operates normally with the $\overline{RESET}$ pin set high. Reference is disabled as $\overline{RESET}$ is set low. | B |
| | | | REF_EN undetermined; external reference connected. An external reference can damage the device if connected to VREFIO for an extended period of time. | A |
| $\overline{RESET}$ | 6 | SCLK | SPI communication corrupted. No SPI communication with the device. UART communication is possible. | B |
| SCLK | 7 | SDI | SPI communication corrupted. No SPI communication with the device.UART communication is possible. | B |
| SDI | 8 | SDO | SPI communication corrupted. No SPI communication with the device. UART communication is possible. An increase in supply current can be observed if the driver of SDI drives SDO. Device damage is possible if connected for an extended period of time. | A |
| SDO | 9 | $\overline{CS}$ | SPI communication corrupted. No SPI communication with the device. UART communication is possible. An increase in supply current can be observed if the driver of $\overline{CS}$ drives SDO. Device damage is possible if connected for an extended period of time. | A |
| $\overline{CS}$ | 10 | CLK_OUT | CLK_OUT disabled. The CLK_OUT pin appears as Hi-Z and does not interfere with $\overline{CS}$ and SPI communication. | D |
| | | | CLK_OUT enabled. SPI communication corrupted. No SPI communication with the device. UART communication is possible. An increase in supply current can be observed if the driver of $\overline{CS}$ drives CLK_OUT. Device damage is possible if connected for an extended period of time. | A |
| CLK_OUT | 11 | IOVDD | CLK_OUT disabled. The CLK_OUT pin appears as Hi-Z and does not interfere with IOVDD. | D |
| | | | CLK_OUT enabled. An increase in supply current is possible when CLK_OUT tries to drive low against IOVDD. Device damage is possible if connected for an extended period of time. | A |
| IOVDD | 12 | VDD | The device can be damaged when VDD is driven to a voltage beyond 2.2 V. | A |
| VDD | 13 | GND | The device is not functional. The internal LDO is shorted to ground. Shorting the pin to ground can increase supply current. Device damage is possible if the pin is connected to GND for an extended period of time. | A |
| GND | 14 | AIN0 | AIN0 forced low. Conversion results for AIN0 are incorrect. | B |
| AIN0 | 15 | POL_SEL/ AIN1 | AIN0 and POL_SEL/AIN1 voltages undetermined; SPECIAL_CFG.AIN1_ENB set to 1. Either or both ADC conversion results for AIN0 and AIN1 can be incorrect. | B |
| | | | AIN0 and POL_SEL/AIN1 voltages are undetermined; SPECIAL_CFG.AIN1_ENB is set to 0. POL_SEL can be set to the wrong polarity depending on the selected DAC VOUT alarm voltage (ALMV_POL). | B |
| POL_SEL/ AIN1 | 16 | PVDD | POL_SEL/AIN1 forced high; SPECIAL_CFG.AIN1_ENB set to 1. Conversion results for AIN1 are incorrect. | B |
| | | | POL_SEL/AIN1 forced high; ADC SPECIAL_CFG.AIN1_ENB set to 0. POL_SEL can be set to the wrong polarity depending on the selected DAC VOUT alarm voltage (ALMV_POL). | B |
| PVDD | 17 | VOUT | VOUT shorted to PVDD. DAC output is shorted and not functional. Shorting the pin to PVDD can increase supply current. Device damage is possible if connected for an extended period of time. | A |

**Table 4-4. Pin FMA for Device Pins Short-Circuited to Adjacent Pin (continued)**

| Pin Name | Pin No. | Shorted to | Description of Potential Failure Effects | Failure Effect Class |
|---|---|---|---|---|
| VOUT | 18 | VREFIO | DAC reference voltage and DAC output voltage are undetermined, and the DAC is not functional. Shorting VOUT to VREFIO can increase supply current. Device damage is possible if connected for an extended period of time. | A |
| VREFIO | 19 | REF_GND | VREFIO forced low; external reference connected. The DAC output is incorrect and not functional. | B |
| | | | VREFIO forced low; internal reference enabled. The DAC output is incorrect and not functional. Shorting the pin to ground can increase the supply current. Device damage is possible if the internal reference is enabled and the pin is connected to GND for an extended period of time. | A |
| REF_GND | 20 | RX_IN | RX_IN pin forced low. DAC output can be incorrect. HART communication is not functional. | B |
| RX_IN | 21 | RX_INF | Incorrect setup for HART input of the device. HART communication can be disrupted or not functional. | B |
| RX_INF | 22 | MOD_OUT | Contention between HART input and output. HART communication is not functional. Device damage is possible if pin is connected to GND for an extended period of time. | A |
| MOD_OUT | 23 | $\overline{\text{ALARM}}$ | Contention between MOD_OUT pin and $\overline{\text{ALARM}}$ pin. HART communication is not functional. ALARM indications are not functional. | B |
| $\overline{\text{ALARM}}$ | 24 | UARTIN | $\overline{\text{ALARM}}$ pin not functional and UART communication contention. SPI communication is possible. An increase in supply current can be observed if UARTIN pulls high and open-drain $\overline{\text{ALARM}}$ pulls low. Device damage is possible if connected for an extended period of time. | A |

**Table 4-5. Pin FMA for Device Pins Short-Circuited to PVDD and IOVDD**

| Pin Name | Pin No. | Description of Potential Failure Effects | Failure Effect Class |
|---|---|---|---|
| UARTIN | 1 | UARTIN forced high. No UART communication to the device. SPI communication is possible. | B |
| UARTOUT | 2 | UARTOUT forced high. No UART communication from the device. SPI communication is possible. An increase in supply current can be observed. Device damage is possible if UARTOUT is connected to supply for extended period of time. | A |
| CD | 3 | CD pin forced high. Shorting the pin to supply can increase the supply current. Device damage is possible if the pin is connected to supply for an extended period of time. | A |
| $\overline{\text{RTS}}$ | 4 | $\overline{\text{RTS}}$ pin forced high. HART communication is not functional. | B |
| REF_EN | 5 | REF_EN forced high. If the internal reference is selected, the device operates normally. | D |
| | | REF_EN forced high. If external reference is connected, device damage is possible if external reference drives VREFIO. | A |
| $\overline{\text{RESET}}$ | 6 | $\overline{\text{RESET}}$ is forced high. The device cannot be reset using the $\overline{\text{RESET}}$ pin, but operates normally. | B |
| SCLK | 7 | SCLK forced high. No SPI communication with the device. UART communication is possible. | B |
| SDI | 8 | SDI forced high. No SPI communication to the device. UART communication is possible. | B |
| SDO | 9 | SDO forced high. No SPI communication from the device. UART communication is possible. An increase in supply current can be observed. Device damage is possible if SDO is connected to supply for an extended period of time. | A |
| $\overline{\text{CS}}$ | 10 | $\overline{\text{CS}}$ forced high. No SPI communication with the device. UART communication is possible. The device operates normally when used in UART communication mode. | B |
| CLK_OUT | 11 | CLK_OUT disabled. The CLK_OUT pin appears as Hi-Z and does not interfere with the supply. | D |
| | | CLK_OUT enabled. An increase in supply current is possible when CLK_OUT tries to drive low against the supply. Device damage is possible if connected for an extended period of time. | A |
| IOVDD | 12 | For this case, IOVDD = PVDD = 3.3 V. No effect. Normal operation. | D |
| VDD | 13 | VDD driven to supply. The device can be damaged when VDD is driven to a voltage beyond 2.2 V. | A |
| GND | 14 | GND tied to supply. The device is not powered and not functional. The supply can draw excessive current. Verify that the absolute maximum ratings for all pins of the device are met; otherwise, device damage is possible. | A |
| AIN0 | 15 | AIN0 forced high. The conversion results for ADC0 are incorrect. | B |
| POL_SEL/ AIN1 | 16 | POL_SEL/AIN1 forced high; SPECIAL_CFG.AIN1_ENB set to 1. The conversion results for AIN1 are incorrect. | B |
| | | POL_SEL/AIN1 forced high; SPECIAL_CFG.AIN1_ENB set to 0. POL_SEL can be set to the wrong polarity depending on the selected DAC VOUT alarm voltage (ALMV_POL). | B |
| PVDD | 17 | No effect. Normal operation. | D |
| VOUT | 18 | VOUT shorted to supply. The DAC output is shorted and not functional. Shorting the pin to supply can increase the supply current. | B |
| VREFIO | 19 | VREFIO shorted to supply. The DAC output is not functional. Shorting the pin to supply can increase the supply current. Device damage is possible if the pin is connected to supply. | A |
| REF_GND | 20 | REF_GND shorted to supply. The DAC is not functional. The supply can draw excessive current. Verify that the absolute maximum ratings for all pins of the device are met; otherwise, device damage is possible. | A |
| RX_IN | 21 | RX_IN pin forced high. HART communication can be disrupted and not functional. Supply can draw excessive current. Device damage is possible if pin is connected to supply. | A |
| RX_INF | 22 | RX_INF pin forced high. HART communication can be disrupted and not functional. Supply can draw excessive current. Device damage is possible if pin is connected to supply. | A |
| MOD_OUT | 23 | MOD_OUT pin forced high. HART communication not functional. Supply can draw excessive current. Device damage is possible if pin is connected to supply. | A |
| $\overline{\text{ALARM}}$ | 24 | $\overline{\text{ALARM}}$ pin forced high. The pin is not functional. Open-drain $\overline{\text{ALARM}}$ pin can be damaged during alarm if directly connected to PVDD. | A |

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