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1 Overview

This document contains information for ADS7954-Q1 (TSSOP 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.

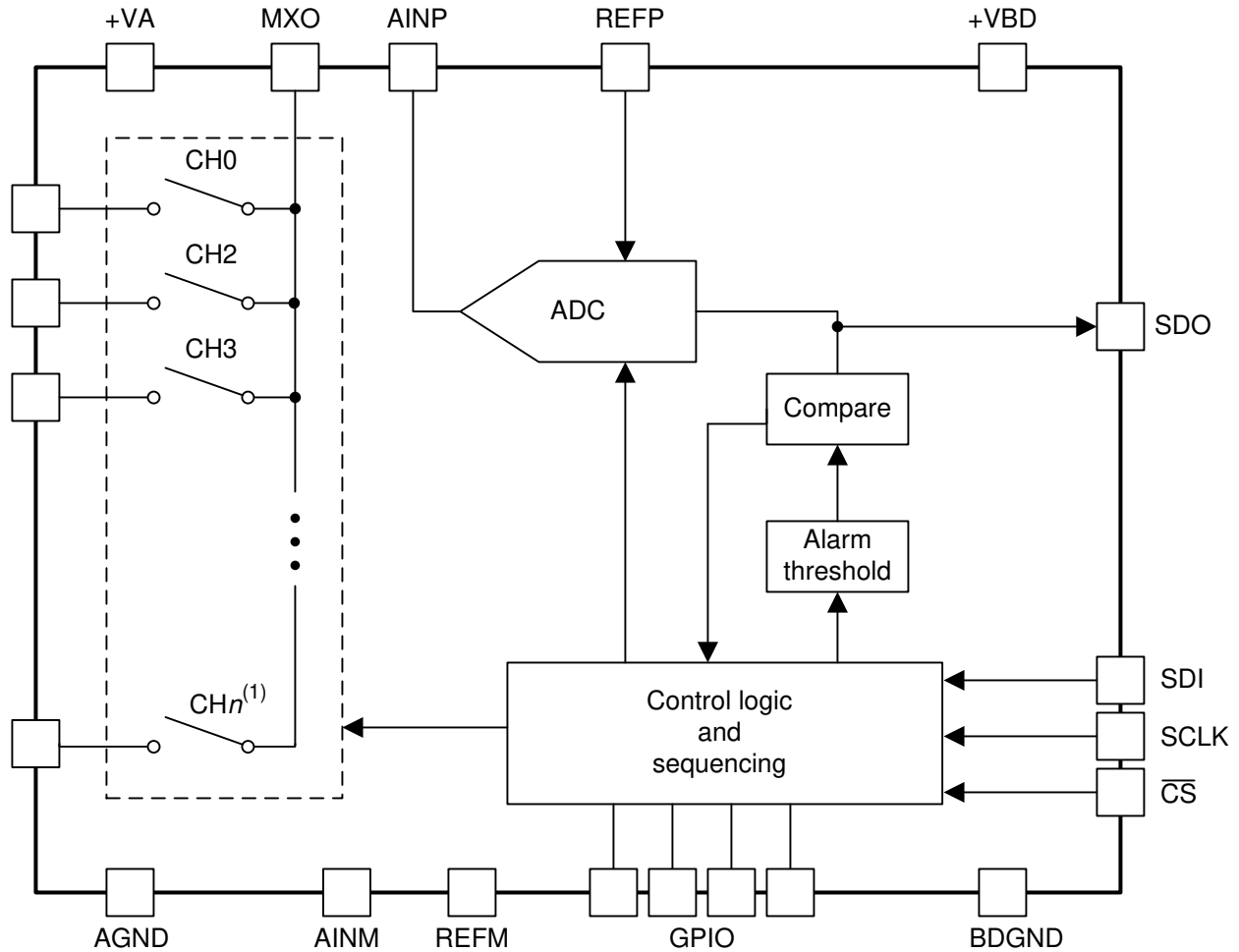


Figure 1-1. Functional Block Diagram

ADS7954-Q1 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 ADS7954-Q1 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	16
Die FIT Rate	2
Package FIT Rate	14

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: 21 mW
- Climate type: World-wide Table 8
- Package factor (λ_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 Digital, analog / mixed	25 FIT	55°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 ADS7954-Q1 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 due to misuse or overstress.

Table 3-1. Die Failure Modes and Distribution

Die Failure Modes	Failure Mode Distribution (%)
Incorrect channel selected	10%
Channel-channel short	10%
ADC output code bit error	20%
ADC gain out of specification	20%
ADC offset out of specification	20%
Communication error	20%

4 Pin Failure Mode Analysis (Pin FMA)

This section provides a Failure Mode Analysis (FMA) for the pins of the ADS7954-Q1. 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 ADS7954-Q1 pin diagram. For a detailed description of the device pins please refer to the *Pin Configuration and Functions* section in the ADS7954-Q1 data sheet.

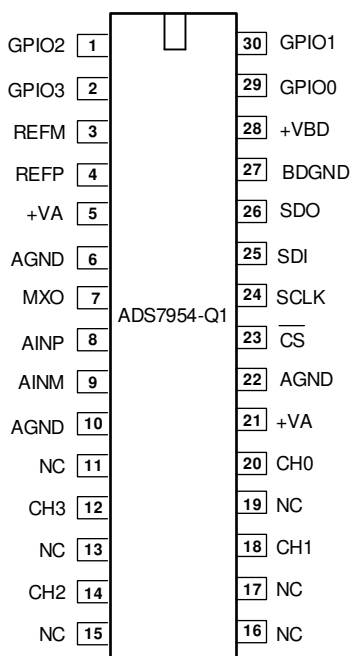


Figure 4-1. Pin Diagram

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

- +VA and +VBD use the same supply voltage.
- AGND, REFM and BDGND use the same GND.
- RC filters on every analog input, CHx. Series resistors are sized to limit the input currents into the analog inputs to <10mA in all circumstances, e.g. also in case device is unpowered and input signal is applied.
- Device is the only slave on the SPI bus.

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

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
GPIO2	1	GPIO2 configured as digital output: GPIO2 stuck low. Increase in supply current when GPIO2 tries to drive high. Device damage may be plausible.	A
		GPIO2 configured as digital input: GPIO2 stuck low. Readback value of GPIO2 will be 0b.	B
GPIO3	2	GPIO3 configured as digital output: GPIO3 stuck low. Increase in supply current when GPIO3 tries to drive high. Device damage may be plausible.	A
		GPIO3 configured as digital input: GPIO3 stuck low. Readback value of GPIO3 will be 0b.	B
REFM	3	No effect. Normal operation.	D
REFP	4	Reference voltage to the ADC will be 0 V as REFP = REFM = Ground. Incorrect conversion result for all channels. Conversion result for all channels will be close to 0x3FF.	B
+VA	5	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
AGND	6	No effect. Normal operation.	D
MXO	7	Conversion results for all channels will be close to 0x000. Multiplexer's analog inputs CH3-CH0 will be connected to Ground through MXO. Increase in current sourced from the analog inputs.	B
AINP	8	External amplifier used between MXO and AINP: Conversion results for all channels will be close to 0x000. External amplifier's output will be connected to Ground.	B
		MXO directly connected to AINP: Conversion results for all channels will be close to 0x000. Multiplexer's analog inputs CH3-CH0 will be connected to Ground through MXO and there will be increase in current sourced from the external circuits driving the analog inputs.	B
AINM	9	No effect. Normal operation.	D
AGND	10	No effect. Normal operation.	D
NC	11	No effect. Normal operation.	D
CH3	12	Conversion result for this analog input channel will be close to 0x000.	B
NC	13	No effect. Normal operation.	D
CH2	14	Conversion result for this analog input channel will be close to 0x000.	B
NC	15	No effect. Normal operation.	D
NC	16	No effect. Normal operation.	D
NC	17	No effect. Normal operation.	D
CH1	18	Conversion result for this analog input channel will be close to 0x000.	B
NC	19	No effect. Normal operation.	D
CH0	20	Conversion result for this analog input channel will be close to 0x000.	B
+VA	21	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
AGND	22	No effect. Normal operation.	D
\overline{CS}	23	\overline{CS} stuck low. No SPI communication with the device possible.	B
SCLK	24	SCLK stuck low. No SPI communication with the device possible.	B
SDI	25	SDI stuck low. Device configuration cannot be modified. Device will remain in previously configured state until reset condition occurs. Device will remain in default configuration after power-up.	B
SDO	26	SDO stuck low. No data readback possible from the device. Increase in supply current when device tries to drive SDO high. Device damage may be plausible.	A
BDGND	27	No effect. Normal operation.	D
+VBD	28	Digital interface not powered up. No SPI communication with device possible. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
GPIO0	29	GPIO0 configured as digital output: GPIO0 stuck low. Increase in supply current when GPIO0 tries to drive high. Device damage may be plausible.	A
		GPIO0 configured as digital input: GPIO0 stuck low. Readback value of GPIO0 will be 0b.	B

Table 4-2. Pin FMA for Device Pins Short-Circuited to Ground (continued)

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
GPIO1	30	GPIO1 configured as digital output: GPIO1 stuck low. Increase in supply current when GPIO1 tries to drive high. Device damage may be plausible.	A
		GPIO1 configured as digital input: GPIO1 stuck low. Readback value of GPIO1 will be 0b.	B

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

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
GPIO2	1	GPIO2 configured as digital output: No logic signaling between GPIO2 and external circuit possible. Otherwise normal operation.	B
		GPIO2 configured as digital input: Readback value of GPIO2 will be unknown.	B
GPIO3	2	GPIO3 configured as digital output: No logic signaling between GPIO3 and external circuit possible. Otherwise normal operation.	B
		GPIO3 configured as digital input: Readback value of GPIO3 will be unknown.	B
REFM	3	Incorrect conversion result for all channels. The ADC reference will connect to ground internally through REFm pin ESD diode. Increased gain error for all channels due to reference voltage drop across ESD diode.	B
REFP	4	Incorrect and unknown conversion result for all channels. Unknown reference voltage to the ADC. The reference circuit may power-up through internal circuit to Power.	B
+VA	5	Device functionality unknown. Device unpowered and not functional if all external analog pins are held low. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible. Device may power up through internal ESD diodes to +VA if voltages above the device's power-on reset threshold are present on any of the analog pins.	A
AGND	6	Device functionality unknown. Device may be unpowered or connect to ground internally through alternate pin ESD diode and power up.	B
MXO	7	External amplifier used between MXO and AINP: Multiplexer's analog inputs CH3-CH0 cannot be connected to the external amplifier's input. Conversion results for all channels will depend on the output voltage of the amplifier driving AINP.	B
		MXO directly connected to AINP: Multiplexer's analog inputs CH3-CH0 cannot be connected to the ADC's input. Conversion results for all channels will be unknown.	B
AINP	8	Conversion results for all channels will be unknown.	B
AINM	9	Conversion results for all channels will be unknown.	B
AGND	10	Device functionality unknown. Device may be unpowered or connect to ground internally through alternate pin ESD diode and power up.	B
NC	11	No effect. Normal operation.	D
CH3	12	Conversion result for this analog input channel will be unknown.	B
NC	13	No effect. Normal operation.	D
CH2	14	Conversion result for this analog input channel will be unknown.	B
NC	15	No effect. Normal operation.	D
NC	16	No effect. Normal operation.	D
NC	17	No effect. Normal operation.	D
CH1	18	Conversion result for this analog input channel will be unknown.	B
NC	19	No effect. Normal operation.	D
CH0	20	Conversion result for this analog input channel will be unknown.	B
+VA	21	Device functionality unknown. Device unpowered and not functional if all external analog pins are held low. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible. Device may power up through internal ESD diodes to +VA if voltages above the device's power-on reset threshold are present on any of the analog pins.	A
AGND	22	Device functionality unknown. Device may be unpowered or connect to ground internally through alternate pin ESD diode and power up.	B
\overline{CS}	23	State of \overline{CS} undetermined. No SPI communication with the device possible.	B

Table 4-3. Pin FMA for Device Pins Open-Circuited (continued)

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
SCLK	24	State of SCLK undetermined. No SPI communication with the device possible.	B
SDI	25	State of SDI undetermined. Device configuration cannot be modified. Device will remain in previously configured state until reset condition occurs. Device will remain in default configuration after power-up.	B
SDO	26	No data readback possible from the device.	B
BDGND	27	Device functionality unknown. Digital interface may be unpowered or power up internally through alternate pin ESD diode to Ground. SPI communication may not be possible with the device.	B
+VBD	28	Digital interface not powered up if all external digital pins are held low. No SPI communication with device possible. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible. Digital interface may power up through internal ESD diodes to DVDD if voltages above the device's power-on reset threshold are present on any of the digital pins.	A
GPIO0	29	GPIO0 configured as digital output: No logic signaling between GPIO0 and external circuit possible. Otherwise normal operation.	B
		GPIO0 configured as digital input: Readback value of GPIO0 will be unknown.	B
GPIO1	30	GPIO1 configured as digital output: No logic signaling between GPIO1 and external circuit possible. Otherwise normal operation.	B
		GPIO1 configured as digital input: Readback value of GPIO1 will be unknown.	B

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

Pin Name	Pin No.	Shorted to	Description of Potential Failure Effect(s)	Failure Effect Class
GPIO2	1	GPIO3	GPIO2 configured as digital output and GPIO3 as digital output: Output voltage level unknown. Increase in supply current when GPIO2 tries to drive low and GPIO3 tries to drive high and vice versa. Device damage may be plausible.	A
			GPIO2 configured as digital output and GPIO3 as digital input: Readback value of GPIO3 will depend on the output drive on GPIO2.	B
			GPIO2 configured as digital input and GPIO3 as digital output: Readback value of GPIO2 will depend on the output drive on GPIO3.	B
			GPIO2 configured as digital input and GPIO3 as digital input: Readback value of GPIO2 and GPIO3 will be the same.	B
GPIO3	2	REFM	GPIO3 configured as digital output: GPIO3 stuck low. Increase in supply current when GPIO3 tries to drive high. Device damage may be plausible.	A
			GPIO3 configured as digital input: GPIO3 stuck low. Readback value of GPIO3 will be 0b.	B
REFM	3	REFP	Incorrect conversion result for all channels. Conversion result will be close to 0x3FF for all channels. Reference voltage to the ADC will be 0 V as REFP = REFM = Ground.	B
REFP	4	+VA	Incorrect conversion result for all channels. Higher gain error for all channels because reference to the ADC is different from the intended REFP voltage. Reference voltage out of specification in case +VA > 3 V.	B
+VA	5	AGND	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
AGND	6	MXO	Conversion results for all channels will be close to 0x000. Multiplexer's analog inputs CH3-CH0 will be connected to Ground through MXO. Increase in current sourced from the analog inputs.	B
MXO	7	AINP	External amplifier used between MXO and AINP: The external amplifier is bypassed. Increased gain error in conversion results if the external amplifier is configured for gain > 1. Conversion results for all channels may have higher error if there are ADC input settling errors when driving AINP directly with MXO.	B
			MXO directly connected to AINP: No effect. Normal operation.	D
AINP	8	AINM	Conversion results for all channels will be close to 0x000.	B

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

Pin Name	Pin No.	Shorted to	Description of Potential Failure Effect(s)	Failure Effect Class
AINM	9	AGND	No effect. Normal operation.	D
AGND	10	NC	No effect. Normal operation.	D
NC	11	CH3	No effect. Normal operation.	D
CH3	12	NC	No effect. Normal operation.	D
NC	13	CH2	No effect. Normal operation.	D
CH2	14	NC	No effect. Normal operation.	D
NC	15	-	Not considered. Corner pin.	D
NC	16	NC	No effect. Normal operation.	D
NC	17	CH1	No effect. Normal operation.	D
CH1	18	NC	No effect. Normal operation.	D
NC	19	CH0	No effect. Normal operation.	D
CH0	20	+VA	Device configured for range 1: Conversion result for this analog input channel will be close to 0x3FF.	B
			Device configured for range 2: Conversion result for this analog input channel will correspond to $(+VA / (2 \times V_{REF})) * 1023$.	B
+VA	21	AGND	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
AGND	22	\overline{CS}	\overline{CS} stuck low. No SPI communication with the device possible.	B
\overline{CS}	23	SCLK	SPI communication corrupted. No SPI communication with the device possible.	B
SCLK	24	SDI	SPI communication corrupted. No SPI communication with the device possible.	B
SDI	25	SDO	SPI communication corrupted. No SPI communication with the device possible. Increase in supply current when host tries to drive SDI low while device tries to drive SDO high and vice versa. Device damage may be plausible.	A
SDO	26	BDGND	SDO stuck low. No data readback possible from the device. Increase in supply current when device tries to drive SDO high. Device damage may be plausible.	A
BDGND	27	+VBD	Digital interface not powered up. No SPI communication with device possible. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
+VBD	28	GPIO0	GPIO0 configured as digital output: GPIO0 stuck high. Increase in supply current when GPIO0 tries to drive low. Device damage may be plausible.	A
			GPIO0 configured as digital input: GPIO0 stuck high. Readback value of GPIO0 will be 1b.	B

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

Pin Name	Pin No.	Shorted to	Description of Potential Failure Effect(s)	Failure Effect Class
GPIO0	29	GPIO1	GPIO0 configured as digital output and GPIO1 as digital output: Increase in supply current when GPIO0 tries to drive low and GPIO1 tries to drive high and vice versa. Device damage may be plausible.	A
			GPIO0 configured as digital output and GPIO1 as digital input: Readback value of GPIO1 will depend on the output drive on GPIO0.	B
			GPIO0 configured as digital input and GPIO1 as digital output: Readback value of GPIO0 will depend on the output drive on GPIO1.	B
			GPIO0 configured as digital input and GPIO1 as digital input: Readback value of GPIO0 and GPIO1 will be the same.	B
GPIO1	30	-	Not considered. Corner pin.	D

Table 4-5. Pin FMA for Device Pins Short-Circuited to supply

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
GPIO2	1	GPIO2 configured as digital output: GPIO2 stuck high. Increase in supply current when GPIO2 tries to drive low. Device damage may be plausible.	A
		GPIO2 configured as digital input: GPIO2 stuck high. Readback value of GPIO2 will be 1b.	B
GPIO3	2	GPIO3 configured as digital output: GPIO3 stuck high. Increase in supply current when GPIO3 tries to drive low. Device damage may be plausible.	A
		GPIO3 configured as digital input: GPIO3 stuck high. Readback value of GPIO3 will be 1b.	B
REFM	3	Incorrect conversion result for all channels. The ADC reference will connect to ground internally through REFM pin ESD diode. Increased gain error for all channels due to reference voltage drop across ESD diode. Increase in supply current through ESD to Ground from REFM pin. Device damage may be plausible.	A
REFP	4	Incorrect conversion result for all channels. Higher gain error for all channels because reference to the ADC is different from the intended REFP voltage. Reference voltage out of specification in case +VA > 3 V.	B
+VA	5	No effect. Normal operation.	D
AGND	6	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
MXO	7	Multiplexer's analog inputs CH3-CH0 will be connected to Power through MXO. Increase in current sunk by the external circuits driving the analog inputs. <ul style="list-style-type: none"> Device configured for range 1: Conversion results for all channels will be close to 0x3FF. Device configured for range 2: Conversion results for all channels will correspond to $(+VA / (2 \times VREF)) * 1023$. 	B
AINP	8	If MXO is directly connected to AINP, multiplexer's analog inputs CH3-CH0 will be connected to Power through MXO and there will be increase in current sunk by the external circuits driving the analog inputs. <ul style="list-style-type: none"> Device configured for range 1: Conversion results for all channels will be close to 0x3FF. Device configured for range 2: Conversion results for all channels will correspond to $(+VA / (2 \times VREF)) * 1023$. 	B
AINM	9	Conversion result for all channels will be close to 0x000.	B
AGND	10	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
NC	11	No effect. Normal operation.	D
CH3	12	Device configured for range 1: Conversion result for this analog input channel will be close to 0x3FF.	B
		Device configured for range 2: Conversion result for this analog input channel will correspond to $(+VA / (2 \times VREF)) * 1023$.	
NC	13	No effect. Normal operation.	D

Table 4-5. Pin FMA for Device Pins Short-Circuited to supply (continued)

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
CH2	14	Device configured for range 1: Conversion result for this analog input channel will be close to 0x3FF.	B
		Device configured for range 2: Conversion result for this analog input channel will correspond to $(+VA / (2 \times VREF)) * 1023$.	
NC	15	No effect. Normal operation.	D
NC	16	No effect. Normal operation.	D
NC	17	No effect. Normal operation.	D
CH1	18	Device configured for range 1: Conversion result for this analog input channel will be close to 0x3FF.	B
		Device configured for range 2: Conversion result for this analog input channel will correspond to $(+VA / (2 \times VREF)) * 1023$.	
NC	19	No effect. Normal operation.	D
CH0	20	Device configured for range 1: Conversion result for this analog input channel will be close to 0x3FF.	B
		Device configured for range 2: Conversion result for this analog input channel will correspond to $(+VA / (2 \times VREF)) * 1023$.	
+VA	21	No effect. Normal operation.	D
AGND	22	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
\overline{CS}	23	\overline{CS} stuck high. No SPI communication with the device possible. SDO will be Hi-Z.	B
SCLK	24	SCLK stuck high. No SPI communication with the device possible.	B
SDI	25	SDI stuck high. Device configuration cannot be modified. Device will remain in previously configured state until reset condition occurs. Device will remain in default configuration after power-up.	B
SDO	26	SDO stuck high. No data readback possible from the device. Increase in supply current when device tries to drive SDO low. Device damage may be plausible.	A
BDGND	27	Device unpowered and not functional. Observe that the absolute maximum ratings for all pins of the device are met, otherwise device damage may be plausible.	A
+VBD	28	No effect. Normal operation.	D
GPIO0	29	GPIO0 configured as digital output: GPIO0 stuck high. Increase in supply current when GPIO0 tries to drive low. Device damage may be plausible.	A
		GPIO0 configured as digital input: GPIO0 stuck high. Readback value of GPIO0 will be 1b.	B
GPIO1	30	GPIO1 configured as digital output: GPIO1 stuck high. Increase in supply current when GPIO1 tries to drive low. Device damage may be plausible.	A
		GPIO1 configured as digital input: GPIO1 stuck high. Readback value of GPIO1 will be 1b.	B

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