



1 Overview

This document contains information for INA186-Q1 (DCK-6, DBV-5, and DDF-8 packages) 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.

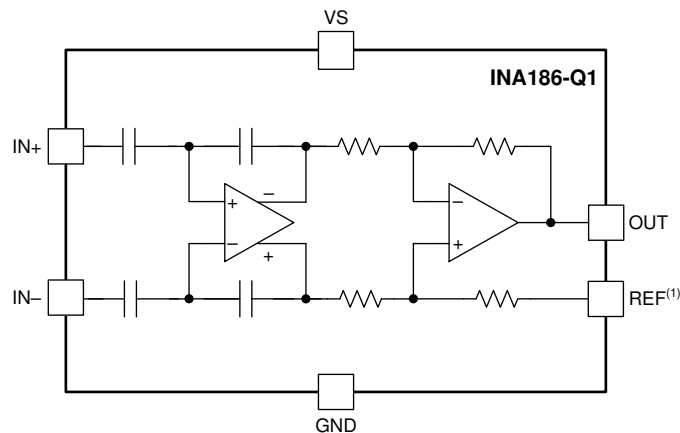


Figure 1-1. Functional Block Diagram

INA186-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

2.1 DCK-6 Package

This section provides Functional Safety Failure In Time (FIT) rates for the DCK-6 package of INA186-Q1 based on two different industry-wide used reliability standards:

- [Table 2-5](#) provides FIT rates based on IEC TR 62380 / ISO 26262 part 11
- [Table 2-6](#) 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	5
Die FIT Rate	3
Package FIT Rate	2

The failure rate and mission profile information in [Table 2-5](#) comes from the Reliability data handbook IEC TR 62380 / ISO 26262 part 11:

- Mission Profile: Automotive Control
- Power dissipation: 25 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
4	CMOS Op amp, comparators, voltage monitors	8 FIT	45°C

The Reference FIT Rate and Reference Virtual T_J (junction temperature) in [Table 2-6](#) 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.

2.2 DBV-5 Package

This section provides Functional Safety Failure In Time (FIT) rates for the DBV-5 package of INA186-Q1 based on two different industry-wide used reliability standards:

- [Table 2-3](#) provides FIT rates based on IEC TR 62380 / ISO 26262 part 11
- [Table 2-4](#) provides FIT rates based on the Siemens Norm SN 29500-2

Table 2-3. 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	4
Die FIT Rate	2
Package FIT Rate	2

The failure rate and mission profile information in [Table 2-3](#) comes from the Reliability data handbook IEC TR 62380 / ISO 26262 part 11:

- Mission Profile: Motor Control from Table 11
- Power dissipation: T25 mW
- Climate type: World-wide Table 8
- Package factor lambda 3 Table 17b
- Substrate Material: FR4
- EOS FIT rate assumed: 0 FIT

Table 2-4. Component Failure Rates per Siemens Norm SN 29500-2

Table	Category	Reference FIT Rate	Reference Virtual T _J
4	Op amp, comparators, voltage monitors	8 FIT	45°C

The Reference FIT Rate and Reference Virtual T_J (junction temperature) in [Table 2-4](#) 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.

2.3 DDF-8 Package

This section provides Functional Safety Failure In Time (FIT) rates for the DDF-8 package of INA186-Q1 based on two different industry-wide used reliability standards:

- [Table 2-5](#) provides FIT rates based on IEC TR 62380 / ISO 26262 part 11
- [Table 2-6](#) provides FIT rates based on the Siemens Norm SN 29500-2

Table 2-5. 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	4
Die FIT Rate	2
Package FIT Rate	2

The failure rate and mission profile information in [Table 2-5](#) comes from the Reliability data handbook IEC TR 62380 / ISO 26262 part 11:

- Mission Profile: Motor Control from Table 11
- Power dissipation: 25 mW
- Climate type: World-wide Table 8
- Package factor lambda 3 Table 17b
- Substrate Material: FR4
- EOS FIT rate assumed: 0 FIT

Table 2-6. Component Failure Rates per Siemens Norm SN 29500-2

Table	Category	Reference FIT Rate	Reference Virtual T _J
4	Op amp, comparators, voltage monitors	8 FIT	45°C

The Reference FIT Rate and Reference Virtual T_J (junction temperature) in [Table 2-6](#) 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 INA186-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 (%)
OUT open (Hi-Z)	10%
OUT to GND	20%
OUT to VS	15%
OUT functional, not in specification	50%
Pin to pin short, any two pins	5%

4 Pin Failure Mode Analysis (Pin FMA)

This section provides a Failure Mode Analysis (FMA) for the pins of the INA186-Q1 (DCK-6, DBV-5, and DDF-8 package). The failure modes covered in this document include the typical pin-by-pin failure scenarios:

- Pin short-circuited to Ground (see [Table 4-2](#), see [Table 4-6](#) and [Table 4-10](#))
- Pin open-circuited (see [Table 4-3](#), see [Table 4-7](#) and [Table 4-11](#))
- Pin short-circuited to an adjacent pin (see [Table 4-4](#), see [Table 4-8](#) and [Table 4-12](#))
- Pin short-circuited to supply (see [Table 4-5](#), see [Table 4-9](#) and [Table 4-13](#))

[Table 4-6](#) through [Table 4-13](#) 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

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

- $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$
- $V_S = 1.8\text{ V}$ to 5.0 V
- $V_{IN+} = 12\text{ V}$
- $V_{REF} = V_S / 2$

4.1 DCK-6 Package

[Figure 4-2](#) shows the INA186-Q1 pin diagram for the DCK-6 package. For a detailed description of the device pins please refer to the 'Pin Configuration and Functions' section in the INA186-Q1 datasheet.

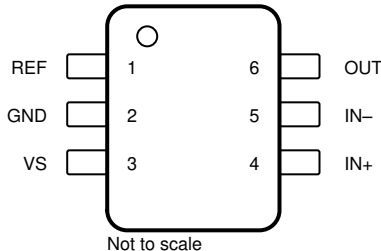


Figure 4-1. Pin Diagram (DCK-6 Package)

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
REF	1	Normal operation if REF pin is at GND potential by design; otherwise the system measurement will be incorrect.	D if REF=GND by design; C otherwise
GND	2	Normal operation.	D
VS	3	Power supply shorted to GND.	B
IN+	4	In high-side configuration, a short from the bus supply to GND will occur.	B
IN-	5	In high-side configuration, a short from the bus supply to GND will occur (through R_{SHUNT}). High current will flow from bus supply to GND. The shunt may be damaged. In low-side configuration, normal operation.	B for high-side; D for low-side
OUT	6	Output will be pulled down to GND and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating, which could cause die junction temperature to exceed 150°C .	B

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

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
REF	1	Output common-mode voltage is not defined. Output will not maintain a linear relationship with differential input voltage.	B
GND	2	When GND is floating, output will be incorrect as it is no longer referenced to GND.	B
VS	3	No power to device. Device may be biased through inputs. Output will be incorrect and close to GND.	B
IN+	4	Shunt resistor is not connected to amplifier. IN+ pin may float to an unknown value. Output will go to an unknown value not to exceed VS or GND.	B
IN-	5	Shunt resistor is not connected to amplifier. IN- pin may float to an unknown value. Output will go to an unknown value not to exceed VS or GND.	B
OUT	6	Output can be left open. There is no effect on the IC, but the output will not be measured.	C

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
REF	1	2 - GND	Normal operation if REF pin is at GND potential by design, otherwise the system measurement will be incorrect.	D if REF=GND by design; C otherwise
GND	2	3 - VS	Power supply shorted to GND.	B
VS	3	4 - IN+	In high-side configuration, VS may be subjected to high voltage bus supply. In low side configuration, device power supply shorted to GND (through R _{SHUNT}).	A for high-side; B for low-side
IN+	4	5 - IN-	Inputs shorted together, so no sense voltage applied. Output will track REF voltage.	B
IN-	5	6 - OUT	In high-side configuration, OUT pin may be subjected to high voltage bus supply. In low side configuration, OUT is shorted to GND, device will not be damaged, but functionality will be affected.	A for high-side; B for low-side
OUT	6	1 - REF	Output will be pulled to REF voltage and output current may be short circuit limited. When left in this configuration for a long time, under high supplies self-heating could cause die junction temperature to exceed 150°C.	B

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
REF	1	Normal operation if REF pin is at VS potential by design; otherwise the system measurement will be incorrect.	D if REF=VS by design; C otherwise
GND	2	Power supply shorted to GND.	B
VS	3	Normal operation.	D
IN+	4	In high-side configuration, device power supply shorted to bus supply. In low-side configuration, device power supply shorted to GND (through R _{SHUNT}).	A for high-side; B for low-side
IN-	5	In high-side configuration, device power supply shorted to bus supply (through R _{SHUNT}). In low-side configuration, device power supply shorted to GND.	A for high-side; B for low-side
OUT	6	Output will be pulled to VS and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating could cause die junction temperature to exceed 150°C.	B

4.2 DBV-5 Package

Figure 4-2 shows the INA186-Q1 pin diagram for the DBV-5 package. For a detailed description of the device pins please refer to the 'Pin Configuration and Functions' section in the INA186-Q1 datasheet.

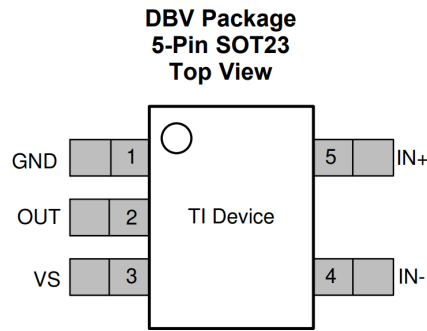


Figure 4-2. Pin Diagram (DBV-5 Package)

Table 4-6. Pin FMA for Device Pins Short-Circuited to Ground

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
GND	1	Normal operation	D
OUT	2	Output will be pulled down to GND and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating, which could cause die junction temperature to exceed 150°C.	B
VS	3	Power supply shorted to GND.	B
IN-	4	In high-side configuration, a short from the bus supply to GND will occur (through RSHUNT). High current will flow from bus supply to GND. The shunt may be damaged. In low-side configuration, normal operation.	B for high-side; D for low-side
IN+	5	In high-side configuration, a short from the bus supply to GND will occur.	B

Table 4-7. Pin FMA for Device Pins Open-Circuited

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
GND	1	When GND is floating, output will be incorrect as it is no longer referenced to GND.	B
OUT	2	Output can be left open. There is no effect on the IC, but the output will not be measured.	C
VS	3	No power to device. Device may be biased through inputs. Output will be incorrect and close to GND.	B
IN-	4	Shunt resistor is not connected to amplifier. IN+ pin may float to an unknown value. Output will go to an unknown value not to exceed VS or GND.	B
IN+	5	Shunt resistor is not connected to amplifier. IN- pin may float to an unknown value. Output will go to an unknown value not to exceed Vs or GND.	B

Table 4-8. 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
GND	1	OUT	Output will be pulled down to GND and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating, which could cause die junction temperature to exceed 150°C.	B
OUT	2	VS	Output will be pulled to VS and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating could cause die junction temperature to exceed 150°C.	C
VS	3	IN-	In high-side configuration, device power supply shorted to bus supply (through RSHUNT). In low-side configuration, device power supply shorted to GND.	A for high-side; B for low-side
IN-	4	IN+	Inputs shorted together, so no sense voltage applied. Output will be close to GND	B
IN+	5	GND	In high-side configuration, a short from the bus supply to GND will occur.	B

Table 4-9. Pin FMA for Device Pins Short-Circuited to supply

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
GND	1	Power supply shorted to GND.	B
OUT	2	Output will be pulled to VS and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating could cause die junction temperature to exceed 150°C.	B
VS	3	Normal operation.	D
IN-	5	In high-side configuration, device power supply shorted to bus supply (through RSHUNT). In low-side configuration, device power supply shorted to GND.	A for high-side; B for low-side
IN+	4	In high-side configuration, device power supply shorted to bus supply. In low-side configuration, device power supply shorted to GND (through RSHUNT).	A for high-side; B for low-side

4.3 DDF-8 Package

Figure 4-3 shows the INA186-Q1 pin diagram for the DDF-8 package. For a detailed description of the device pins please refer to the 'Pin Configuration and Functions' section in the INA186-Q1 datasheet.

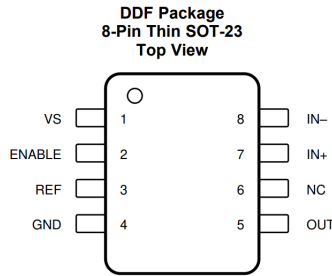


Figure 4-3. Pin Diagram (DDF-8 Package)

Table 4-10. Pin FMA for Device Pins Short-Circuited to Ground

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
VS	1	Power supply shorted to GND.	B
ENABLE	2	The device is off, the supply current is reduced, and the output is placed in a high-impedance state	C
REF	3	Normal operation if REF pin is at GND potential by design; otherwise the system measurement will be incorrect.	D if REF=GND by design; C otherwise
GND	4	Normal operation	D
OUT	5	Output will be pulled down to GND and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating, which could cause die junction temperature to exceed 150°C.	B
NC	6	Normal operation	D
IN+	7	In high-side configuration, a short from the bus supply to GND will occur (through RSHUNT). High current will flow from bus supply to GND. The shunt may be damaged. In low-side configuration, normal operation	B for high-side; D for low-side
IN-	8	In high-side configuration, a short from the bus supply to GND will occur.	B

Table 4-11. Pin FMA for Device Pins Open-Circuited

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
VS	1	No power to device. Device may be biased through inputs. Output will be incorrect and close to GND.	B
ENABLE	2	State of device undetermined.	B
REF	3	Output common-mode voltage is not defined. Output will not maintain a linear relationship with differential input voltage.	B
GND	4	When GND is floating, output will be incorrect as it is no longer referenced to GND.	B
OUT	5	Output can be left open. There is no effect on the IC, but the output will not be measured.	C
NC	6	Normal operation	D
IN+	7	Shunt resistor is not connected to amplifier. IN+ pin may float to an unknown value. Output will go to an unknown value not to exceed VS or GND.	B
IN-	8	Shunt resistor is not connected to amplifier. IN+ pin may float to an unknown value. Output will go to an unknown value not to exceed VS or GND.	B

Table 4-12. 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
VS	1	ENABLE	The device is on and functions as a current sense amplifier.	D if ENABLR=VS by design; C otherwise
ENABLE	2	REF	Device mode and output voltage level will be affected	D if ENABLR=REF by design; C otherwise

Table 4-12. 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
REF	3	GND	Normal operation if REF pin is at GND potential by design; otherwise the system measurement will be incorrect.	D if REF=GND by design; C otherwise
GND	4	OUT	Output will be pulled down to GND and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating, which could cause die junction temperature to exceed 150°C.	B
OUT	5	NC	Normal operation	D
NC	6	IN+	Normal operation	D
IN+	7	IN-	Inputs shorted together, so no sense voltage applied. Output will be close to GND	B
IN-	8	VS	In high-side configuration, device power supply shorted to bus supply (through RSHUNT). In low-side configuration, device power supply shorted to GND.	A for high-side; B for low-side

Table 4-13. Pin FMA for Device Pins Short-Circuited to supply

Pin Name	Pin No.	Description of Potential Failure Effect(s)	Failure Effect Class
VS	1	Normal operation.	D
ENABLE	2	The device is on and functions as a current sense amplifier.	D if ENABL=VS by design; C otherwise
REF	3	Normal operation if REF pin is at VS potential by design; otherwise the system measurement will be incorrect.	D if REF=VS by design; C otherwise
GND	4	Power supply shorted to GND.	B
OUT	5	Output will be pulled to VS and output current will be short circuit limited. When left in this configuration for a long time, under high supplies self-heating could cause die junction temperature to exceed 150°C.	B
NC	6	Normal operation	D
IN+	7	In high-side configuration, device power supply shorted to bus supply. In low-side configuration, device power supply shorted to GND (through RSHUNT).	A for high-side; B for low-side
IN-	8	In high-side configuration, device power supply shorted to bus supply (through RSHUNT). In low-side configuration, device power supply shorted to GND.	A for high-side; B for low-side

5 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (March 2020) to Revision A (April 2022) Page

- Added the DBV and DDF packages to the Functional Safety document..... 1

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