Functional Safety Information

TRS3232E-Q1 Functional Safety FIT Rate, FMD and Pin FMA

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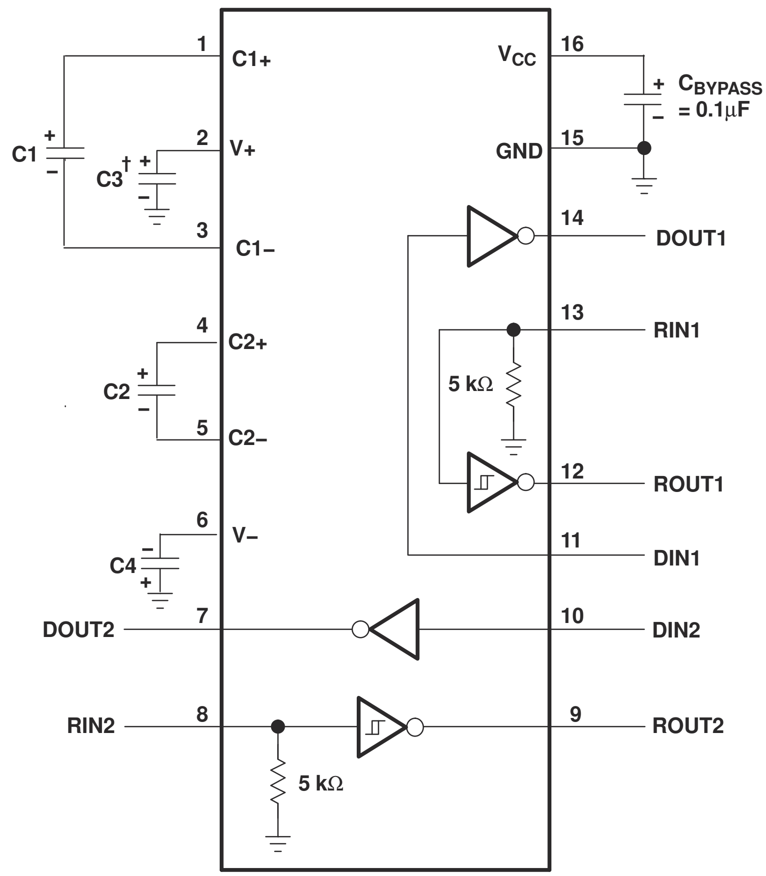
1 Overview

This document contains information for the TRS3232E-Q1 (TSSOP (PW) 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 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.



† C3 can be connected to V_{CC} or GND.

NOTES: A. Resistor values shown are nominal.

B. Nonpolarized ceramic capacitors are acceptable. If polarized tantalum or electrolytic capacitors are used, they should be connected as shown.

V_{CC} vs CAPACITOR VALUES

V_{CC}	C1	C2, C3, C4
3.3 V ± 0.3 V	0.1 µF	0.1 µF
5 V ± 0.5 V	0.047 µF	0.33 µF
3 V to 5.5 V	0.1 µF	0.47 µF

Figure 1-1. Functional Block Diagram

The TRS3232E-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 the TRS3232E-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	11
Die FIT rate	3
Package FIT rate	8

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 or figure 16
- Power dissipation: 100mW
- Climate type: World-wide table 8 or figure 13
- Package factor (lambda 3): From table 17b or figure 15
- 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, or 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 the TRS3232E-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 resulting from misuse or overstress.

Table 3-1. Die Failure Modes and Distribution

Die Failure Modes	Failure Mode Distribution (%)
Charge pump failure	25
Line-driver failure	50
Receiver failure	15
Short circuit of any two I/O pins or I/O pin fault	10

4 Pin Failure Mode Analysis (Pin FMA)

This section provides a failure mode analysis (FMA) for the pins of the TRS3232E-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 TRS3232E-Q1 pin diagram. For a detailed description of the device pins, see the *Pin Configuration and Functions* section in the TRS3232E-Q1 datasheet.

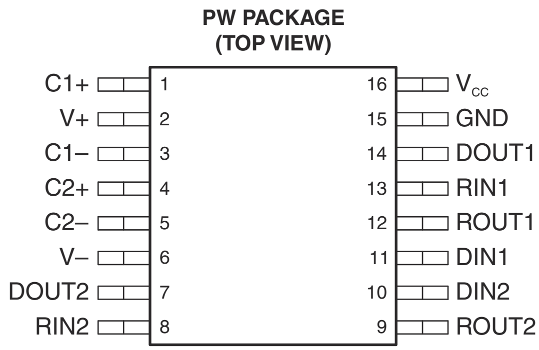


Figure 4-1. Pin Diagram

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

- The device is connected to another RS232 transceiver through a cross-over or null cable.
- An MCU or processor GPO and GPI is connected to the DIN and ROUT pins of the device.
- TTL = transistor to transistor logic, which are the pins on the device that interface with the processor or MCU.

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

Pin Name	Pin No.	Description of Potential Failure Effects	Failure Effect Class
C1+	1	The device is no longer functional due to a disruption of the charge pump circuit. The RS232 bus is no longer operational.	B
V+	2	The device is no longer functional due to a disruption of the charge pump circuit. The RS232 bus is no longer operational.	B
C1-	3	The device is no longer functional due to a disruption of the charge pump circuit. The RS232 bus is no longer operational.	B
C2+	4	The device is no longer functional due to a disruption of the charge pump circuit. The RS232 bus is no longer operational.	B
C2-	5	The device is no longer functional due to a disruption of the charge pump circuit. The RS232 bus is no longer operational.	B
V-	6	The device is no longer functional due to a disruption of the charge pump circuit. The RS232 bus is no longer operational.	B

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

Pin Name	Pin No.	Description of Potential Failure Effects	Failure Effect Class
DOUT2	7	The output does not have wide swings and the data integrity is effected. The receiver node interprets a low signal since most Vth- levels are shifted above GND. This interpretation results in a short circuit which causes V+ and V- to collapse. A brownout or deregulated power rail occurs if the power rail cannot handle the collapse.	B
RIN2	8	*Case 1*: The RS232 cable is not connected. • No issues. *Case 2*: The RS232 cable is connected. • The received output does not have wide swings and the data integrity is effected. The receiver node potentially interprets a low signal since most Vth- levels are shifted above GND. This interpretation results in a short circuit which causes V+ and V- to collapse on the driver node. A brownout or deregulated power rail occurs on the driver node if the power rail cannot handle the collapse, while the power rail of the receiver node is not impacted.	B
ROUT2	9	The output is not effected when the output is a logic low. If the output is a logic high, contention occurs which appears as a short circuit that can effect the power rail and cause a brownout or deregulated output. The ROUT PFET saturates during the logic high and a long term short to GND causes damage to the device. The device loses functionality.	A
DIN2	10	Transmission through the RS232 driver is no longer possible. The GPIO of the processor or MCU that is connected to DIN demonstrates high current draw when driven high, which potentially causes the power rail to brownout or deregulate. The device is not expected to be damaged, but the device loses functionality.	B
DIN1	11	Transmission through the RS232 driver is no longer possible. The GPIO of the processor or MCU that is connected to DIN demonstrates high current draw when driven high, which potentially causes the power rail to brownout or deregulate. The device is not expected to be damaged, but the device loses functionality.	B
ROUT1	12	The output is not effected when the output is a logic low. If the output is a logic high, contention occurs which appears as a short circuit that can effect the power rail and cause a brownout or deregulated output. The ROUT PFET saturates during the logic high and a long term short to GND causes damage to the device. The device loses functionality.	A
RIN1	13	Case 1: The RS232 cable is not connected. • No issues. Case 2: The RS232 cable is connected • The received output does not have wide swings and the data integrity is effected. The receiver node potentially interprets a low signal since most Vth- levels are shifted above GND. This interpretation results in a short circuit which causes V+ and V- to collapse on the driver node. A brownout or deregulated power rail occurs on the driver node if the power rail cannot handle the collapse, while the power rail of the receiver node is not impacted.	B
DOUT1	14	The output does not have wide swings and the data integrity is effected. The receiver node interprets a low signal since most Vth- levels are shifted above GND. This interpretation results in a short circuit which causes V+ and V- to collapse. A brownout or deregulated power rail occurs if the power rail cannot handle the collapse.	B
GND	15	The expected connection to GND.	D
V_{CC}	16	Short to GND; the power supply deregulates or experiences a brownout. The device is not expected to be damaged, but the device loses functionality.	B

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

Pin Name	Pin No.	Description of Potential Failure Effects	Failure Effect Class
C1+	1	The charge pump circuit does not work. The device loses overall functionality.	B
V+	2	The charge pump circuit does not work. The device loses overall functionality.	B
C1-	3	The charge pump circuit does not work. The device loses overall functionality.	B
C2+	4	The charge pump circuit does not work. The device loses overall functionality.	B
C2-	5	The charge pump circuit does not work. The device loses overall functionality.	B

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

Pin Name	Pin No.	Description of Potential Failure Effects	Failure Effect Class
V-	6	The charge pump circuit does not work. The device loses overall functionality.	B
DOUT2	7	The RS232 output no longer works. The DOUT2 channel loses functionality but the other pins still work.	B
RIN2	8	The RS232 output no longer works. The RIN2 channel loses functionality but the other pins still work.	B
ROUT2	9	The TTL output no longer works. The ROUT2 channel loses functionality but the other pins still work.	B
DIN2	10	The TTL input no longer works. The DIN2 channel loses functionality but the other pins still work.	B
DIN1	11	The TTL input no longer works. The DIN1 channel loses functionality but the other pins still work.	B
ROUT1	12	The TTL output no longer works. The ROUT1 channel loses functionality but the other pins still work.	B
RIN1	13	The RS232 input no longer works. The RIN1 channel loses functionality but the other pins still work.	B
DOUT1	14	The RS232 output no longer works. The DOUT1 channel loses functionality but the other pins still work.	B
GND	15	A device without a GND reference causes currents from other pins to leak into blocks not designed for this scenario and causes damage.	A
V_{CC}	16	The device is not expected to be damaged, but the device is no longer operational.	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
C1+	1	V+	The charge pump circuit is disrupted. The device is no longer functional.	B
V+	2	C1-	The charge pump circuit is disrupted. The device is no longer functional.	B
C1-	3	C2+	The charge pump circuit is disrupted. The device is no longer functional.	B
C2+	4	C2-	The charge pump circuit is disrupted. The device is no longer functional.	B
C2-	5	V-	The charge pump circuit is disrupted. The device is no longer functional.	B
V-	6	DOUT2	The charge pump circuit is disrupted. The device is no longer functional.	B
DOUT2	7	RIN2	The RS232 bus loses functionality and contention occurs when the cable is connected to either DOUT2 or RIN2. Both channel 2 circuits lose functionality.	B
ROUT2	9	DIN2	The RS232 bus loses functionality. ROUT is in contention with the GPO of the processor or MCU, which results in power supply issues. Long term contention on ROUT causes damage to the device.	A
DIN2	10	DIN1	The GPO pins of the MCU or processor are shorted together and this causes contention. The device is not damaged, but the device potentially loses functionality.	B
DIN1	11	ROUT1	The ROUT pin can swing negative and damage the DIN pin. The device loses functionality and damage occurs.	A
ROUT1	12	RIN1	The RS232 driver on the opposite side of the cable swings the voltage negative when the cable is connected to RIN1, which damages ROUT. The device also loses functionality due to contention from ROUT and the opposite RS232 driver.	A
RIN1	13	DOUT1	The RS232 bus loses functionality and contention occurs when the cable is connected to either RIN1 or DOUT1. Both channel 1 circuits lose functionality.	B
DOUT1	14	GND	DOUT1 loses functionality due to a short to GND.	B
GND	15	Vcc	A short circuit potentially causes the power supply to deregulate or brownout. The device is not expected to be damaged, but the device potentially loses functionality.	B

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

Pin Name	Pin No.	Description of Potential Failure Effects	Failure Effect Class
C1+	1	The charge pump circuit does not work. The device loses overall functionality.	B
V+	2	The charge pump circuit does not work. The device loses overall functionality.	B
C1-	3	The charge pump circuit does not work. The device loses overall functionality.	B
C2+	4	The charge pump circuit does not work. The device loses overall functionality.	B
C2-	5	The charge pump circuit does not work. The device loses overall functionality.	B
V-	6	The charge pump circuit does not work. The device loses overall functionality.	B
DOUT2	7	The output does not have wide swings and the data integrity is effected. The receiver node interprets a high signal. This interpretation results in a short circuit which causes V- to collapse. A brownout or deregulated power rail occurs if the power rail cannot handle the collapse.	B
RIN2	8	Case 1: The RS232 cable is not connected. • No issues. Case 2: The RS232 cable is connected. • The received output does not have wide swings and the data integrity is effected. The receiver node potentially interprets a high signal since most Vth- levels are shifted above GND. This interpretation results in a short circuit which causes V- to collapse on the driver node. A brownout or deregulation on the driver node occurs if the power rail cannot handle the collapse, while the power rail of the receiver node is not impacted.	B
ROUT2	9	The output is not effected when the output is a logic high. If the output is a logic low, contention occurs which appears as a short circuit that can effect the power rail and causes a brownout or deregulated output. The ROUT PFET saturates during the logic low, and a long term short to V_{CC} causes damage to the device. The device loses functionality.	A
DIN2	10	Transmission through the RS232 driver is no longer possible. The GPIO of the processor or MCU that is connected to DIN demonstrates high current draw when driven low, which potentially causes the power rail to brownout or deregulate. The device is not expected to be damaged, but the device loses functionality.	B
DIN1	11	Transmission through the RS232 driver is no longer possible. The GPIO of the processor or MCU that is connected to DIN demonstrates high current draw when driven low, which potentially causes the power rail to brownout or deregulate. The device is not expected to be damaged, but the device loses functionality.	B
ROUT1	12	The output is not effected when the output is a logic high. If the output is a logic low, contention occurs which appears as a short circuit that can effect the power rail and cause a brownout or deregulated output. The ROUT PFET saturates during the logic low, and a long term short to V_{CC} causes damage to the device. The device loses functionality.	A
RIN1	13	Case 1: The RS232 cable is not connected. • No issues. Case 2: The RS232 cable is connected • The received output does not have wide swings and the data integrity is effected. The receiver node potentially interprets a high signal. This interpretation results in a short circuit which causes V- to collapse on the driver node. A brownout or deregulation on the driver node occurs if the power rail cannot handle the collapse, while the power rail of the receiver node is not impacted.	B
DOUT1	14	The output does not have wide swings and the data integrity is effected. The receiver node interprets a high signal. This interpretation results in a short circuit which causes V- to collapse. A brownout or deregulated power rail occurs if the power rail cannot handle the collapse.	B
GND	15	A short circuit to V_{CC} causes the power supply to deregulate or brownout. The device is not expected to be damaged, but the device is not operational.	B
V_{CC}	16	The expected connection to V_{CC}.	D

5 Revision History

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

DATE	REVISION	NOTES
June 2026	*	Initial Release