ISL72027ASEH, ISL72027CSEH

Single Event Effects (SEE) Testing

TR048
Rev.0.00
Mar 13, 2017

1. Overview

The intense proton and heavy ion environment encountered in space applications can cause a variety of Single Event Effects (SEE) in electronic circuitry, including Single Event Upset (SEU), Single Event Transient (SET), Single Event Functional Interrupt (SEFI), Single Event Gate Rupture (SEGR), Single Event Burnout (SEB), and Single Event Latch-Up (SEL). SEE can lead to system-level performance issues including disruption, degradation, and destruction. For predictable and reliable space system operation, individual electronic components should be characterized to determine their SEE response. This report discusses the results of SEE testing performed on the ISL72027ASEH CAN transceiver. Since the ISL72027CSEH is the same silicon die this report applies to it as well.

1.1 Product Description

The ISL72026ASEH, ISL72027ASEH, and ISL72028ASEH are a family of radiation tolerant Controller Area Network (CAN) bus transceivers. Parts with a “C” suffix rather than the “A” are identical silicon and so have identical SEE performance. These two part types are minor design variants of the progenitor ISL72026SEH, ISL72027SEH, and ISL72028SEH. The basic difference between the “A” and “C” suffix variant parts and the originals is that the transmitter slew rate performance has been modified to better accommodate 500kbps data rates. The designs of the “A” and “C” suffix parts and the original design parts share better than 90% of the circuits in common and so have virtually identical SEE performance. The parts are designed to meet ISO11898-2 physical layer specifications. The parts are fabricated in Intersil's proprietary BCD SOI process with deep trench isolation. The ISL7202xASEH family of parts are bond options of the same silicon die. Further description and explanation of the differences between the parts can be found in the datasheets.

1.2 Related Literature

- For a full list of related documents, visit our website
    - ISL72026ASEH, ISL72027ASEH, and ISL72028ASEH
- White Paper: Using CAN Bus Serial Communications in Space Flight Applications

2. SEE Test Objectives

The ISL72027ASEH was tested to determine its susceptibility to destructive single event effects (collectively referred to as SEB, but to also include SEL and SEGR) and to characterize its Single Event Transient (SET) behavior over various operating conditions. Since the family of parts utilizes the same silicon with bond-out options, it was determined that testing the ISL72027ASEH would serve to characterize all three bond out part options. More description of the part differences is provided in the following two paragraphs. The report will refer only to the ISL72027ASEH with the understanding that the results apply equally to the other two members of the family, the ISL72026ASEH and ISL72028ASEH. The results also apply to the ISL7202xCSEH family as they are identical silicon. Further reference to parts will be limited to the ISl7202xASEH family with the understanding that it also applies to the ISL7202xCSEH family.

The ISL72026ASEH has an input (Pin 5) dedicated to the Loopback (LBK) function, which when enabled causes the digital value of the transmitter input (D, Pin 1) to be echoed to the receiver output (R, Pin 4) without being transmitted to the bus pins (CANH, CANL). On the ISL72027ASEH and ISL72028ASEH, Pin 5 is reassigned by a bonding option to be a reference voltage (V_{REF}) intended to provide a reference termination to the bus lines. Although the LBK is not bonded out in the ISL72027ASEH, it is still active circuitry internal to the part and is subject to SEE events. So testing the ISL72027ASEH still tests the LBK function for SET induced assertion. All that is lost in testing the ISL72027ASEH rather than the ISL72026ASEH is that the part is not tested while in the LBK mode. Since this is a diagnostic mode and is expected to be active only a very small fraction of the operational life, it does not seem to represent a statistically important mode for SEE events. The jeopardy is that a SET could momentarily take the part out of LBK, but this would be an extremely unlikely event if LBK is not a dominant operational mode.

The ISL72028ASEH differs from the ISL72027ASEH in that the RS pin (Pin 8) when pulled to V_{CC} will invoke a Low-Power Shutdown (LPSD) mode rather than the Listen Mode (LM) of the ISL72027ASEH. Either the LM or the LPSD will disable the transmitter. What is lost in testing the ISL72027ASEH is the event where an SET triggers the ISL72028ASEH out of LPSD. Such an event would be of little interest to the operation of the system so it is not perceived as an important omission.

3. SEE Test Facility

Testing was performed at the Texas A & M University (TAMU) Radiation Effects Facility of the Cyclotron Institute heavy ion facility. This facility is coupled to a K500 super-conducting cyclotron, which is capable of generating a wide range of particle beams with the various energy, flux, and fluence levels needed for advanced radiation testing. The devices under test (DUTs) were located in air at 40mm-50mm (depending on ion species) from the Aramica window for the ion beam. Ion LET values quoted are at the DUT surface. Signals were communicated to and from the DUT test fixture through 20 foot cables connecting to the control room. Testing was carried out on October 25, 2015 and August 7, 2016.

4. SEE Test Set-up

SEE testing was carried out with the samples in an active configuration. The schematic of the ISL72027ASEH SEE test fixture used is shown in Figure 4.1. This schematic shows direct access to the CANH/L bus pins for monitoring and indirect access through 30Ω resistors for biasing. The cabling connected to the CANH/L pins present 700pF to GND due to the 20 foot cable connecting the DUT to the oscilloscopes in the control room for SET testing. Other supplies and signals indicated by arrows were also cabled to the control room.

Two instantiations of the schematic on a single board allowed two ISL72027ASEH to be simultaneously irradiated for SEE testing. The two parts were monitored separately. Parts were packaged in the production ceramic flatpack and had their lids removed for the SEE testing. For SEB, the parts' key currents and VREF voltage were monitored before and after irradiation to determine if any change had been induced. For SET testing, the bus pins (CANH and CANL) and the received signal, R, were monitored by an oscilloscope. In static SET testing, any change in R triggered an oscilloscope capture. In dynamic SET testing, the bus and receiver were monitored for changes in the bit stream resulting from the provided input signal. For dynamic inputs, if the received bit stream at R deviated from the set duty cycle (nominally 50%) by ±10% an oscilloscope capture was triggered and the event was stored for later review.

The parts tested for SET came from lot J84095.1 (part # B2784-X18) and the parts for testing SEB came from lot J84095.2 (part # B2784-X28). The parts tested for SET were modified in first metal by Focused Ion Beam (FIB) techniques to correct a minor problems seen on these parts. The receiver exhibited small transition glitches that could interfere with SET triggering based on the received signal behavior. The FIB was not a schematic change to the part. The FIB disconnected a piece of unused metal that was causing the receiver glitch due to noise coupling. These changes were metal fixes instituted in the final product and so the FIB modified units accurately represent the final product. The parts tested for SEB were the final modification versions.

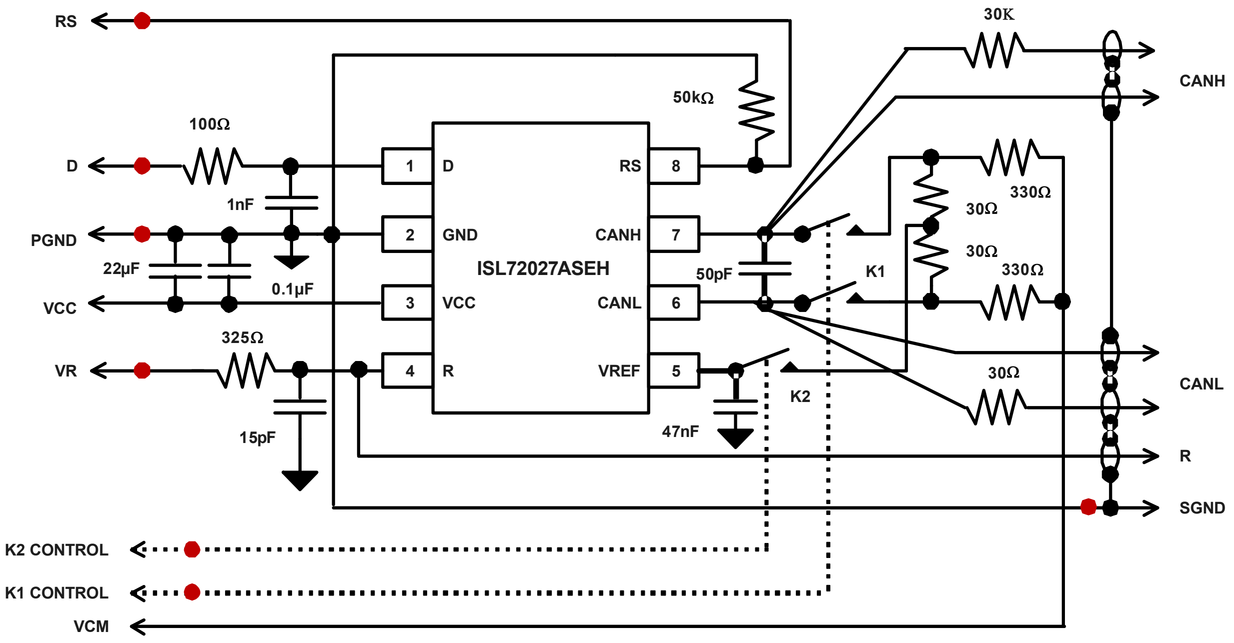

Figure 4.1 **Schematic of the ISL72027ASEH SEE test configuration. Connection to CANH/L through resistors allows setting bus voltage. Direct connections allow monitoring bus voltage at the unit. Note that V_{REF} can be monitored at the external connection VCM when K2 is closed and K1 is open.**

5. Damaging SEE Testing of the ISL72027ASEH CAN Transceiver

Four units of the ISL72027ASEH were irradiated for the purposes of testing for damaging SEE. The testing cited here was done on August 27, 2016. Damaging SEE can actually be SEL, SEGR, or SEB, but for convenience here they are all lumped under the single acronym SEB. Four currents and the V_{REF} output voltage were monitored as in Table 5.1 to determine if permanent change was induced during irradiations. After initial measurements according to Table 5.1, a set of four irradiations was performed as listed in Table 5.2. Each irradiation was done with 2.954GeV Au (gold) at 0° incidence for a calculated surface LET = 86MeV•cm^2/mg to a fluence of 1x10^{7}ion/cm^2 per irradiation at flux of approximately 5x10^{4}ion/(cm^2*s). The complement of four irradiations accounted for 55krad of total dose. The device case temperature was at ambient, +25ºC ±10°C for the irradiations. The ICC and ICM were measured before and after each individual irradiation in the condition used for the irradiation to look for indications of damage in changes of those parameters. At the end of the set of four irradiations, the parameters in Table 5.1 were again measured to look for any changes.

The 50kHz data signal allowed for the common-mode voltage to dominate the bus pins during the recessive periods but still exercised switching conditions. The 47nF capacitor on V_{REF} and the resistors in the VCM path set the time constant of the common-mode voltage and required the 50kHz signal rate to allow the common-mode voltage full settling time during recessive periods.

Table 5.3 presents the log of the ICC and ICM measurements made for each irradiation run at the conditions described in Table 5.2. The pre and post data is also reduced to a percentage delta and is presented in Table 5.3. The small percentage changes noted were considered to be within measurement error and interpreted as indicative of no SEE damage. Table 5.4 presents the measurements of monitor parameters in Table 5.1 made both before and after the grouping of four irradiations along with the deltas registered over those irradiations. Changes were 1% or less and are again considered to be within measurement error. On the basis of these tests the part is found to be free of damaging SEE up to LET = 86MeV•cm^2/mg (Au at 0º incidence) and the conditions listed in Table 5.2.

Table 5.1 Monitor measurements and conditions for damaging SEE detection. OP = Open and CL = Closed. Measurements of these parameters were made at the start and end of the four SEB tests listed in Table 5.2. Oscilloscope channels are indicated by “CH”.

Measurements Made	Electrical Conditions for Measurement									
	RS (V)	D	V_{CC} (V)	VR (V)	K1	K2	V_{CM} (V)	CANH	CANL	R
I_{CM} (µA) at V_{CM} = -7V	GND	3.6	3.6	OP	CL	OP	-7.0	OP	OP	OP
I_{CM} (µA) at V_{CM} = +12V	GND	3.6	3.6	OP	CL	OP	+12.0	OP	OP	OP
V_{REF} at V_{CM} (V)	GND	3.6	3.6	OP	OP	CL	OP	OP	OP	OP
I_{CC} (mA) Dynamic Fast Unloaded	GND	0-3.6V 250kHz	3.6	OP	OP	OP	OP	OP	OP	OP
I_{CC} (mA) Dynamic Slow Loaded	OP	0-3.6V 250kHz	3.6	1.7V	CL	CL	OP	OP	OP	OP

Table 5.2 Damaging SEE tests at extreme supply and common-mode voltages run on ISL72027ASEH and run at ambient temperature (approximately +25°C). OP = Open and CL = Closed.

Tests	Comment	RS (kΩ)	D (V)	V_{CC} (V)	K1	K2	V_{CM} (V)
SEB1	Cold Spare	50	5.5	OP	CL	CL	-20
SEB2	Cold Spare	50	5.5	OP	CL	CL	+20
SEB3	Slow Op	50	0-5.5V 50kHz	5.5	CL	CL	-20
SEB4	Slow Op	50	0-5.5V 50kHz	5.5	CL	CL	+20

Table 5.3 Supply current monitors I_{CC} and I_{CM} for each irradiation with Au at 0° for LET = 86MeV•cm^2/mg to 1x10^{7}ion/cm^2 for each irradiation of the ISL72027ASEH.

Irradiation Tests		DUT1		DUT2		DUT3		DUT4	
		I_{CC} (mA)	I_{CM} (mA)	I_{CC} (mA)	ICM (mA)	I_{CC} (mA)	I_{CM} (mA)	I_{CC} (mA)	I_{CM} (mA)
SEB1	Pre		0.0062		0.0082		0.0074		0.0066
	Post		0.0057		0.0077		0.007		0.0065
	Delta		-8.1%		-6.1%		-5.4%		-1.5%
SEB2	Pre		0.0068		0.0079		0.0071		0.0069
	Post		0.0063		0.0073		0.0069		0.0064
	Delta		-7.4%		-7.6%		-2.8%		-7.2%
SEB3	Pre	7.727	67.65	7.364	67.37	7.423	67.23	7.823	68.13
	Post	7.813	68.53	7.532	68.573	7.508	68.32	7.819	68.54
	Delta	1.1%	1.3%	2.3%	1.8%	1.1%	1.6%	-0.1%	0.6%
SEB4	Pre	95.92	91.93	96.104	91.163	96.043	91.06	96.44	92.21
	Post	94.946	90.155	95.985	91.052	95.989	91.033	95.32	91.054
	Delta	-1.0%	-1.9%	-0.1%	-0.1%	-0.1%	0.0%	-1.2%	-1.3%

Table 5.4 Parametric monitors for each set of four irradiations called out in Table 5.2. Irradiation was with Au at 0° incidence for effective LET of 86MeV•cm^2/mg and each set of four irradiations of Table 5.2 having a total of 4x10^{7}ion/cm^2.

		I_{CM} (µA) at V_{CM} = -7V	I_{CM} (µA) at V_{CM} = +12V	V_{REF} at V_{CM} (V)	I_{CC} (mA) Unloaded Fast	I_{CC} (mA) Loaded Slow
DUT1	Pre	679	732	1.78	4.23	22.05
	Post	672	725	1.77	4.23	22.09
	Delta	-1.0%	-1.0%	-0.1%	0.1%	0.2%
DUT2	Pre	682	732	1.78	4.17	21.10
	Post	678	729	1.78	4.16	21.10
	Delta	-0.6%	-0.4%	0.0%	-0.1%	0.0%
DUT3	Pre	679	730	1.77	4.15	20.98
	Post	673	725	1.77	4.15	20.96
	Delta	-0.9%	-0.7%	0.0%	-0.1%	-0.1%
DUT4	Pre	681	734	1.78	4.23	22.10
	Post	676	731	1.78	4.23	22.10
	Delta	-0.7%	-0.4%	0.0%	-0.1%	0.0%

All of the damaging SEE testing presented here indicated that no damage was incurred with ions of LET = 86MeV•cm^2/mg, and with V_{CM} to ±20V, and V_{CC} either open or at 5.5V.

6. SET Testing of the ISL72027ASEH CAN Transceiver at Ag (LET = 43MeV•cm^2/mg)

Testing for Single Event Transients (SET) was carried out using silver (Ag) at an initial 1.634GeV for a surface LET = 43MeV•cm^2/mg. A summary of the conditions tested and the SET counts resulting appear in Table 6.1. No SET were recorded for the static conditions of either recessive or dominant bus bias. The dynamic captures were triggered by the midspan receiver duty cycle falling outside the range of 40% to 60% with the nominal duty cycle of 50%. The cross section of the dynamic SET captures was a strong function of the transmitter slew rate selected, with the slow slew (RS = 50kΩ) generating about 25 times the cross section as seen with the fast slew setting (RS grounded).

Table 6.1 Static captures were for any change of R state, while dynamic captures were taken for R duty cycle outside of 40% to 60%. The irradiations were with Ag at normal incidence for LET = 43MeV•cm^2/mg and the device at ambient temperature (~+25°C). A fluence of 5x10^{6}ions/cm^2 was done for each irradiation.

Test Conditions V_{CC} = 3.0V	DUT1 Events	DUT2 Events	DUT3 Events	DUT4 Events	Net Cross Section (cm^2)
Static Recessive, RS = 0Ω (Fast)	0	0	0	0	0
Static Recessive, RS = 50Ω (Slow)	0	0	0	0	0
Driven V_{OD} = 1.5V, RS = 0Ω (Fast)	0	0	0	0	0
Driven V_{OD} = 1.5V, RS = 50Ω (Slow)	0	0	0	0	0
D = 500kHz, RS = 0Ω (Fast)	4	3	5	4	8.0x10^{-7}
D = 500kHz, RS = 50kΩ (Slow)	115	125	143	100	2.4x10^{-5}

Examples of the worst transients captured are presented in Figure 6.1 and Figure 6.2.

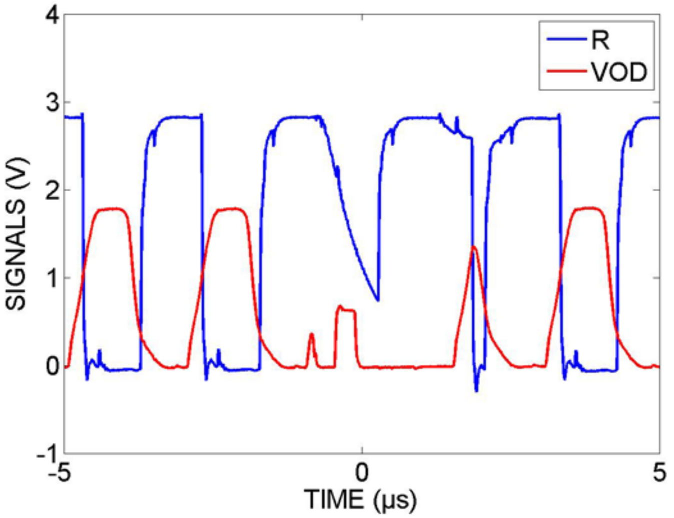

Figure 6.1 The worst case event captured for RS = 50kΩ (slow slewing transmitter) and D = 500kHz with LET = 43MeV•cm^2/mg. Two consecutive dominant bits have been mostly lost for a possible SET duration of just under 3µs. Both transmitter (V_{OD}) and receiver (R) signals have been impacted.

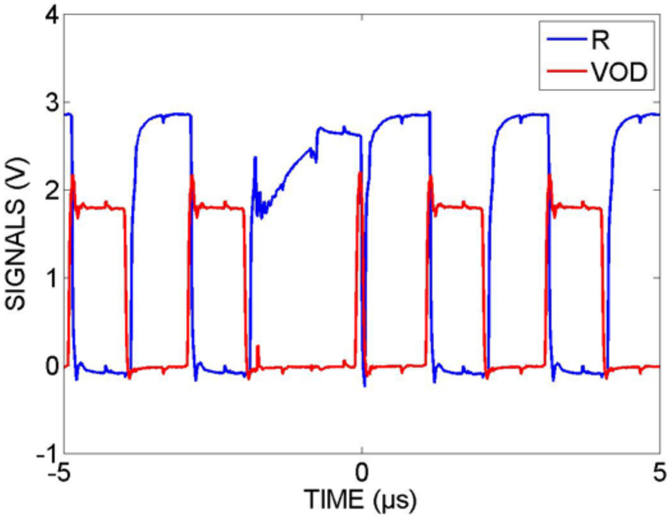

Figure 6.2 The worst case event captured for RS = 0Ω (fast slewing transmitter) and D = 500kHz with LET = 43MeV•cm^2/mg. A full dominant bit has been lost for a possible interruption of 2µs. Both transmitter (V_{OD}) and receiver (R) signals have been impacted.

7. SET Testing of the ISL72027ASEH CAN Transceiver at Cu (LET = 20MeV•cm^2/mg)

Single event testing was repeated using Cu at an initial 1.259GeV for an effective LET = 20Me•Vcm^2/mg. The static testing was not repeated as it yielded no SET with Ag irradiation. The summary of SET testing is presented in Table 7.1 below. The captured SET were again subjected to post analysis and the worst case events are presented in Figure 7.1 and Figure 7.2.

Table 7.1 Dynamic captures were taken for R duty cycle outside of 40% to 60%. The irradiations were with Cu at normal incidence for an LET = 20MeV•cm^2/mg and the device at ambient temperature (approximately +25ºC). A fluence of 1x10^{7}ions/cm^2 was done for each irradiation.

Test Conditions V_{CC} = 3.0V	DUT1 Events	DUT2 Events	DUT3 Events	DUT4 Events	Net Cross Section (cm^2)
D = 500kHz, RS = 0 (Fast)	0	0	2	0	5.0x10^{-8}
D = 500kHz, RS = 50k (Slow)	13	12	27	4	1.4x10^{-6}

Examples of the worst transients captured are presented in Figure 7.1 and Figure 7.2.

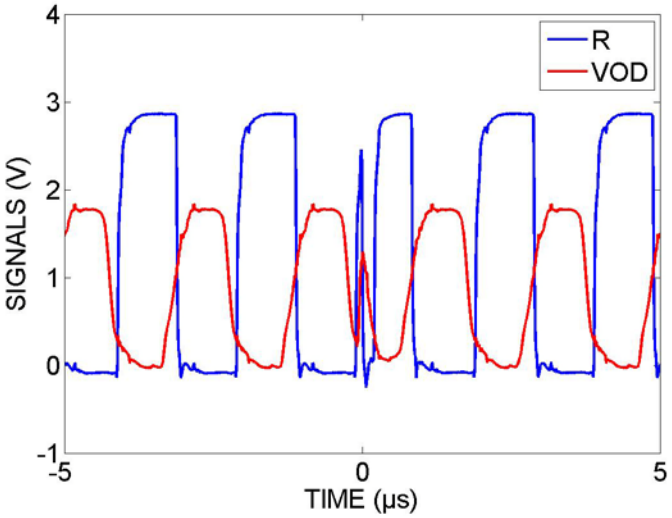

Figure 7.1 The worst case event captured for RS = 50kΩ (slow slewing transmitter) and D = 500kHz with LET = 20MeV•cm^2/mg. Both transmitter (V_{OD}) and receiver (R) signals have been impacted, but the SET is confined to be within a single bit width (1µs).

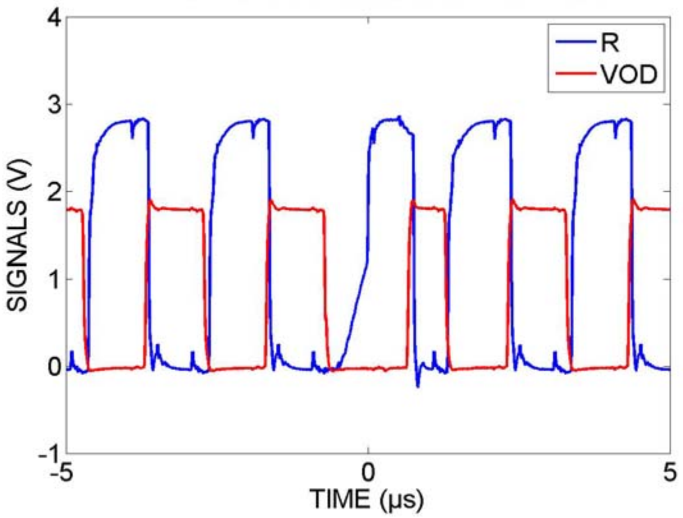

Figure 7.2 The worst case event captured for RS = 0Ω (fast slewing transmitter) and D = 500kHz with LET = 20MeV•cm^2/mg. Both transmitter (V_{OD}) and receiver (R) signals have been impacted, but the SET spans only slightly more than a single bit (1µs).

8. SET Testing of the ISL72027ASEH CAN Transceiver at Ar (LET = 8.5MeV•cm2/mg)

Single event testing was repeated using Ar at initial 0.599GeV and an effective LET = 8.5MeV•cm^2/mg. The static testing was not repeated as they yielded no SET with Ag irradiation. The summary of SET testing is presented in Table 8.1 below. The SET cross section for the slow receiver transition was considerably smaller than with Cu and the fast receiver transition did not produce any SET captures.

Table 8.1 Dynamic captures were taken for R duty cycle outside of 40% to 60%. The irradiations were with Ar at normal incidence for an LET = 8.5 MeV•cm^2/mg and the device at ambient temperature (~+25ºC). A fluence of 1x10^{7}ions/cm^2 was done for each irradiation.

Test Conditions V_{CC} = 3.0V	DUT1 Events	DUT2 Events	DUT3 Events	DUT4 Events	Net Cross Section (cm^2)
D = 500kHz, RS = 0 (Fast)	0	0	0	0	$\leq 2.5\text{x}10^{-8}$
D = 500kHz, RS = 50k (Slow)	1	1	0	1	$7.5\text{x}10^{-8}$

The captured SET were again subjected to post analysis and the worst case event is presented in Figure 8.1.

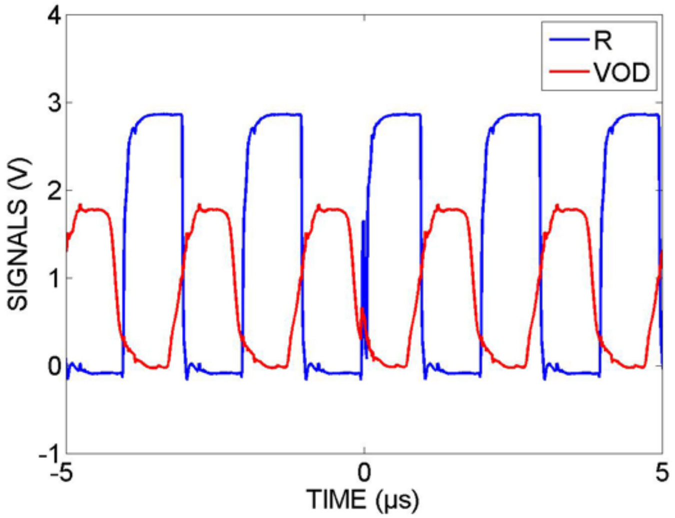

Figure 8.1 The worst case event captured for RS = 50kΩ (slow slewing transmitter) and D = 500kHz with LET = 8.5MeV•cm^2/mg. Both transmitter (V_{OD}) and receiver (R) signals have been impacted, but the SET is confined to be well within a single bit width (< 1µs).

9. Conclusions

9.1 Damaging SEE

Testing of the ISL72027ASEH at case temperatures of approximately +25°C ambient and 0° incidence Au at 86MeV•cm^2/mg did not yield damaging SEE effects with a supply of V_{CC} = 5.5V and the CAN bus common-mode (CANH, CANL) at, ±20V. The tests were run on four parts to 1x10^{7}ions/cm^2 on each of four irradiation runs per part including both polarities of common-mode for both cold sparing and transmission at 50kHz. It is consequently concluded that the part is immune to damaging SEE effects at 86MeV•cm^2/mg while operating at or below the voltages of V_{CC} = 5.5V and bus common-mode voltages of ±20V.

9.2 Single Event Transients

The ISL72027ASEH did not exhibit any static case SET when tested with an LET of 43MeV•cm^2/mg according to the conditions in Table 6.1. Monitoring a static bus condition of either recessive or driven to a dominant value of V_{OD} of 1.5V did not result in any SET on the receiver (R) output. Since there were no SET at LET of 43MeV•cm^2/mg, these tests were not repeated a lower LET levels.

The ISL72027ASEH did exhibit dynamic SET susceptibility at LET = 43, 20, and 8.5MeV•cm^2/mg when operated transmitting a 1Mbps signal stream. SET were defined as any received bit stream with a duty cycle outside of 40% to 60% for a nominal 50% duty cycle bit stream. The largest dynamic SET cross section was as high as 2.4x10^{-5}cm^2 for operation at the slow transmitter slew rate and with LET = 43MeV•cm^2/mg. At the fastest transmitter slew rate and LET = 43MeV•cm^2/mg, the cross section dropped to 8.0x10^{-7}cm^2. Examples of these SET appear in Figure 6.1 and Figure 6.2. At an LET of 8.5MeV•cm^2/mg, the cross section of slow slew rate SET dropped to 7.5x10^{-8}cm^2. It was noted that the recorded SET event consisted of SET on both the received signal, R, and on the bus signals, CANH and CANL. This indicates that the SET registered started with events in the transmitter and were simply reflected in the receiver. No events consisting only of a receiver SET were recorded. Given that these cross sections are so low and that the transients are limited to a couple of bits at 1Mbps rates, the standard CAN Bus error correction protocol should be able to absorb these events without significant system performance impact.

IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers skilled in the art designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only for development of an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising out of your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Rev.1.0 Mar 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

© 2020 Renesas Electronics Corporation. All rights reserved.