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TEST REPORT

IS-1825ASRH

Single Event Effects (SEE)

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Introduction

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 Latch-Up (SEL), Single Event Gate Rupture (SEGR), and single event burnout (SEB). 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 IS-1825ASRH representing the IS-1825AS family of PWM controllers.

Product Description

The IS-1825AS family of parts are single event and total dose hardened pulse-width modulators and are designed to be used in high-frequency, switching power supplies in either voltage or current-mode configurations. The design includes a precision voltage reference, a low power start-up circuit, a high-frequency oscillator, a wide-band error amplifier, and a fast current-limit comparator.

The IS-1825AS represents a family of parts consisting of the IS-1825ASRH, IS-1825BSRH, IS-1825BSEH, ISL71823ASRH, and ISL71823BSRH. The IS-1825xSxH parts are all the same die differing only in production testing. The ISL71823xSRH parts are a metal variant of the IS-1825xSxH die that puts the two outputs in phase. The “EH” suffix parts are wafer-by-wafer acceptance tested to 50krad(Si) at 0.01rad(Si)/s. Because they are all the same silicon die, the SEE results presented here should apply to all the parts in the IS-1825AS family.

The parts used for the testing described here were taken from production inventory. The lids were removed to allow irradiation.

Related Literature

For a full list of related documents, visit our website

- IS-1825ASRH, IS-1825BSRH, IS-18525BSEH, ISL71823ASRH, and ISL71823BSRH product pages

1. SEE Test Objectives

The IS-1825ASRH was tested to determine its susceptibility to destructive single event effects (referred to herein as SEB) and to characterize its Single Event Transient (SET) behavior over different operating conditions.

1.1 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. Further details on the test facility can be found at the website (http://cyclotron.tamu.edu/). The Devices Under Test (DUTs) were located in air at 40mm from the Aramica window for the ion beam. Ion LET values are quoted at the DUT surface. Signals were communicated to and from the DUT test fixture through 20 foot cables connecting to the control room. The testing reported here was conducted on May 6 of 2017 for SEB and June 23, 2017 for SET.

1.2 SEE Test Set-Up

SEE testing was carried out with the samples in an open-loop active configuration. The schematic of the IS-1825ASRH SEE test fixture is shown in Figure 1. R_2 and C_2 were selected to program the oscillator frequency to approximately 400kHz and V1 was adjusted to produce approximately a 20% duty cycle at OUTA and OUTB. Two units were mounted on every test board so that two units could be simultaneously irradiated and tested. A 20 foot cable was used to connect supplies and observation instruments at the control room to the parts in the irradiation room. The same configuration was used to test for both damaging SEE and for transient SEE.

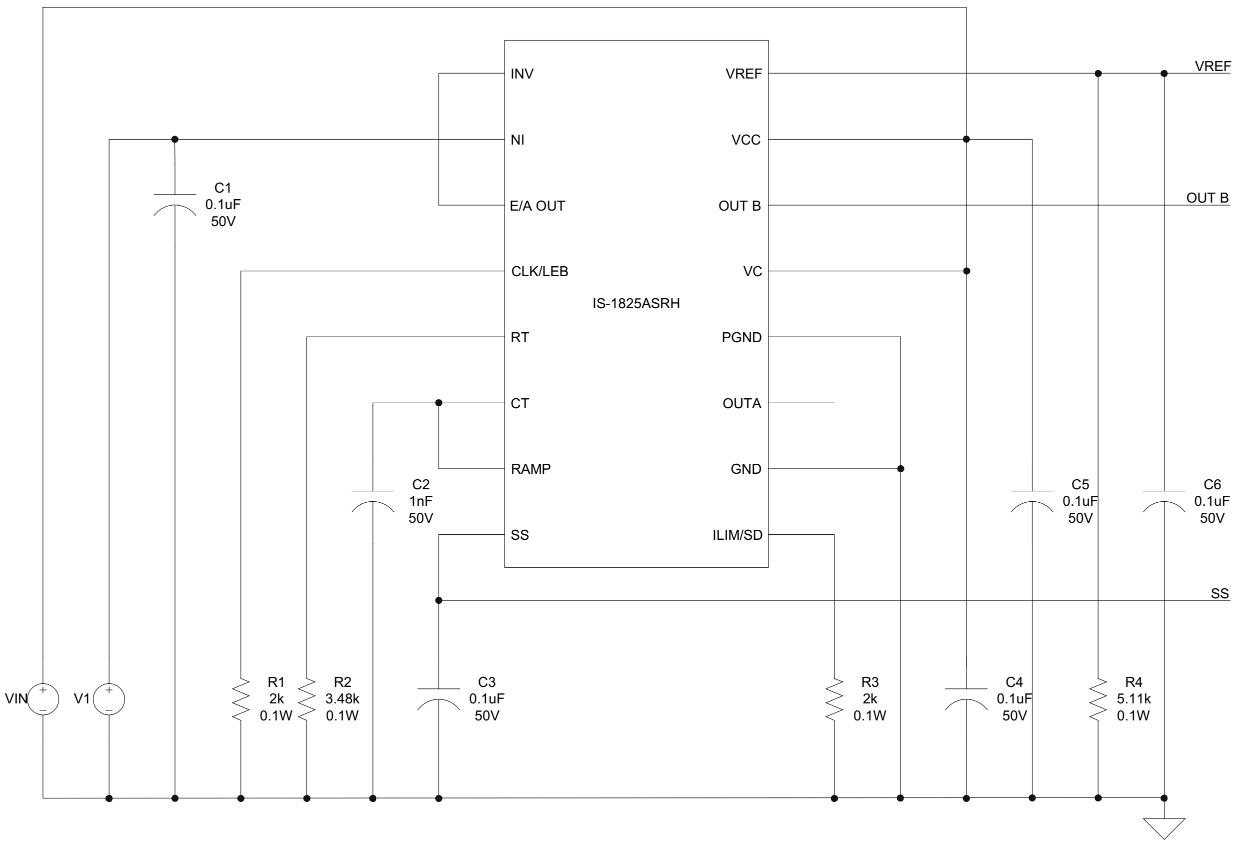

Figure 1. IS-1825ASRH SEE Test Circuit Schematic

1.3 Destructive SEE Testing of the IS-1825AS with LET = 86.3MeV•cm^2/mg

Destructive SEE testing (termed SEB here, because the process is dielectrically isolated and so is immune to SEL) of the IS-1825ASRH proceeded with two V_{CC} values (20V and 24V) and checking four operating parameters (operating ICC, OUTA pulse width, OUTB pulse width, and V_{REF}) before and after irradiation to identify any damaging effects through changes in the parameters. Irradiation was done with 2.954 GeV gold (Au) at normal incidence for LET at the die surface (after an Aramica window and a 40mm air gap) of 86.3MeV•cm^2/mg at a case temperature of +125°C ±10°C. A summary of the SEB testing results is presented in Table 1 on page 3.

Table 1. IS-1825AS SEB Monitor Measurements

			I_{CC} (mA)	OUTA Pulse (ns)	OUTB Pulse (ns)	V_{REF} (V)
V_{CC} = 20V	DUT1	Pre	62	453	455	5.14
		Post	63	449	453	5.10
		Delta	1.6%	-0.9%	-0.4%	-0.8%
	DUT2	Pre	61	438	441	5.10
		Post	65	443	445	5.14
		Delta	6.6%	1.1%	0.9%	0.8%
	DUT3	Pre	70	452	455	5.14
		Post	71	448	452	5.14
		Delta	1.4%	-0.9%	-0.7%	0.0%
	DUT4	Pre	67	471	472	5.14
		Post	66	465	460	5.14
		Delta	-1.5%	-1.3%	-2.5%	0.0%
V_{CC} = 24V	DUT1	Pre	86	458	459	5.12
		Post	86	454	456	5.12
		Delta	0.0%	-0.9%	-0.7%	-0.1%
	DUT2	Pre	81	440	442	5.10
		Post	84	438	437	5.10
		Delta	3.7%	-0.5%	-1.1%	0.0%
	DUT3	Pre	84	430	434	5.14
		Post	87	427	429	5.13
		Delta	3.6%	-0.7%	-1.2%	-0.2%
	DUT4	Pre	92	430	432	5.11
		Post	91	434	436	5.11
		Delta	-1.1%	0.9%	0.9%	-0.1%

Note: VCC = 20V and 24V with LET = 86 MeV•cm^2/mg to a fluence of $1x10^7$ion/cm^2 with T_{CASE} = +125°C ±10°C.

The data presented in Table 1 supports the conclusion that the IS-1825AS is immune to damaging SEE for operation at V_{CC} = 24V and case temperature of +125°C when irradiated with gold ions of LET 86.3MeV•cm^2/mg at normal incidence. The changes observed in monitored parameters were generally under 1%. In the case of I_{CC} there was one change at 6.6% (DUT2 at V_{CC} = 20V) and two (DUT2 and DUT3 at V_{CC} = 24V) at just under 4%. These I_{CC} changes were within part-to-part variation and so were deemed not to be indicative of damaging effects.

1.4 SET Testing of the IS-1825ASRH PWM Controller

The SET testing of the IS-1825ASRH monitored events on the signals OUTA, OUTB, SS, and VREF. All four signals were captured on each of four oscilloscopes. The first oscilloscope triggered on OUTA pulse-width deviation of ±10% from a nominal of approximately 450ns. The second oscilloscope captured SET on changes in the OUTA period between rising edges of ±20% on the 2.4µs nominal. The third oscilloscope triggered on soft-start (SS) falling below 4V from a nominal 5.1V. The fourth oscilloscope was set to trigger on V_{REF} moving outside a ±100mV window. A summary of the event counts appears in Table 2 on page 4. Because the V_{REF} did not record any SET, it is omitted from Table 2.

Table 2. Summary of Output SET Counts for Irradiation Testing

LET ($MeV•cm^2/mg$), Species, Fluence, and Flux Normal Incidence	Device	OUTA Events ±10% of PW	OUTA Events ±20% Period	SS SEFI Events VSS<4V
86.3 Au $2x10^6 ion/cm^2$ $1.0x10^4 ion/(s*cm^2)$	DUT1	1315	762	21
	DUT2	1183	722	22
	DUT3	1417	836	30
	DUT4	1393	715	0
42.8 Ag $2x10^6 ion/cm^2$ $1.0x10^4 ion/(s*cm^2)$	DUT5	1234	426	28
	DUT6	697	244	0
	DUT7	811	279	0
	DUT8	913	323	0
28.3 Kr $4x10^6 ion/cm^2$ $2.0x10^4 ion/(s*cm^2)$	DUT9	522	237	0
	DUT10	564	228	0
	DUT11	480	162	0
	DUT12	523	204	0
19.9 Cu $4x10^6 ion/cm^2$ $2.0x10^4 ion/(s*cm^2)$	DUT9	351	114	0
	DUT10	387	142	0
	DUT11	339	127	0
	DUT12	427	134	0

Note: Different parts were used for each of the first three different LET conditions. The four parts used for Kr were also used for Cu.

All the SET captured for LET 19.9 and 28.3MeV•cm^2/mg for OUTA pulse width variation (third column) were simply distortions of an OUTA pulse with some associated disturbance of the switching period. No explicitly triggered monitoring of OUTB was made, but the OUTB signal was captured on OUTA triggered events. At the two higher LET the majority of SET were also of this isolated pulse disturbance type. Of this type of disturbances the largest and smallest OUTA pulse widths for LET = 86.3MeV•cm^2/mg are represented in Figures 2 and 3 on page 5. The single pulse disturbances for lower LET were essentially the same as those presented, but the nominal cross sections for the events were lower.

The OUTA pulse period trigger used in the fourth column of Table 2 yielded different SET than the pulse-width trigger of the third column. The most extreme period variations constituted missing pulses of either OUTA or OUTB and a concomitant half-cycle shift in the pulse trains of OUTA and OUTB. An example of a missing OUTA pulse and the doubling up of the OUTB pulses is shown in Figure 4 on page 6.

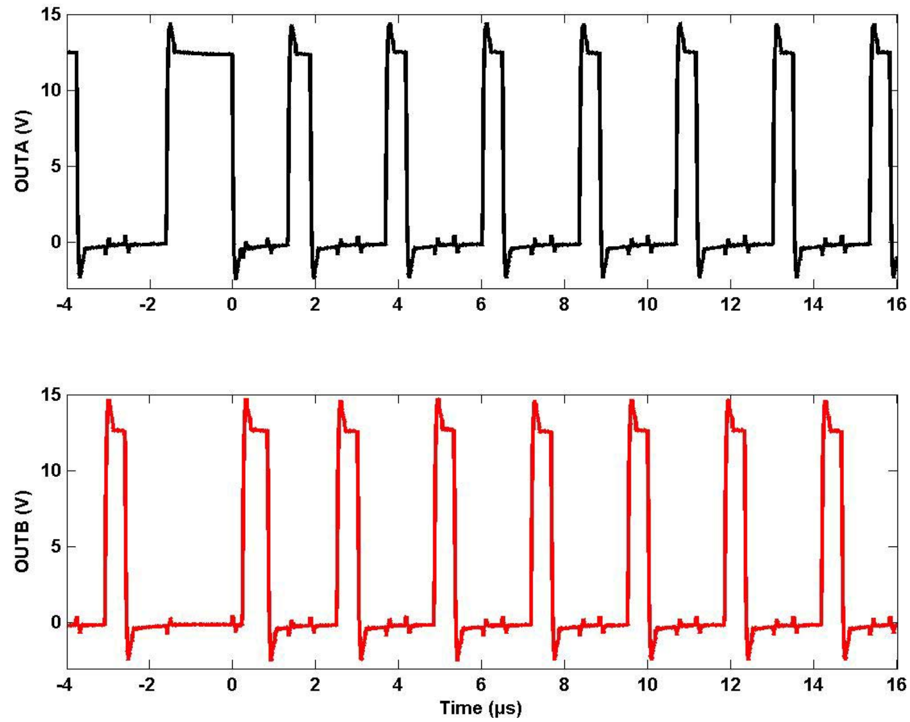

Figure 2. The Longest OUTA SET Obtained for DUT2 at 86.3MeV•cm^2/mg

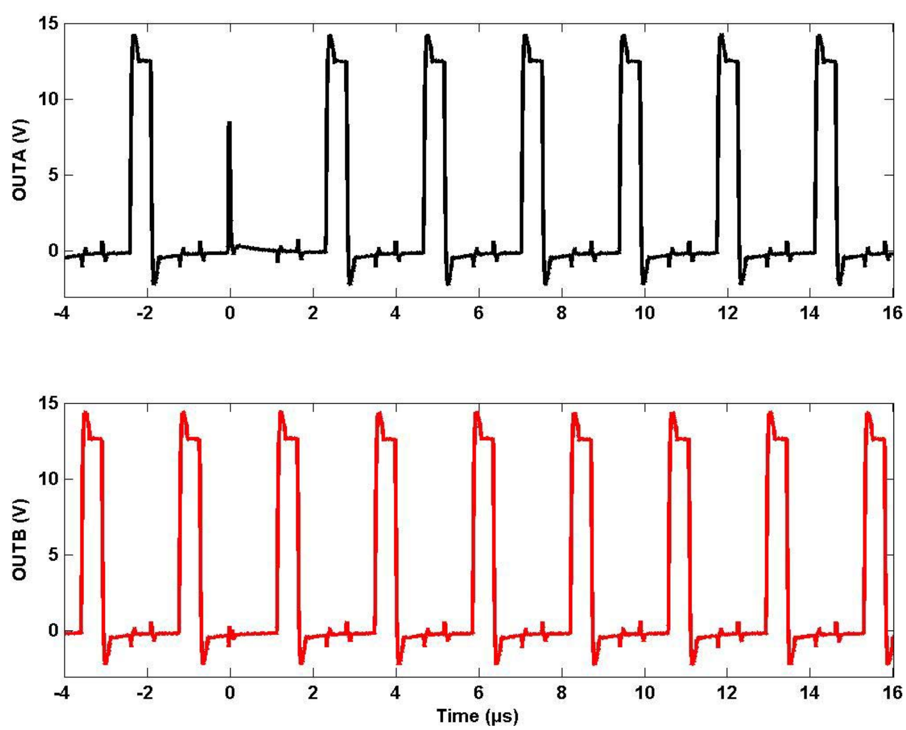

Figure 3. The Shortest OUTA SET Obtained for DUT4 at 86.3MeV•cm^2/mg

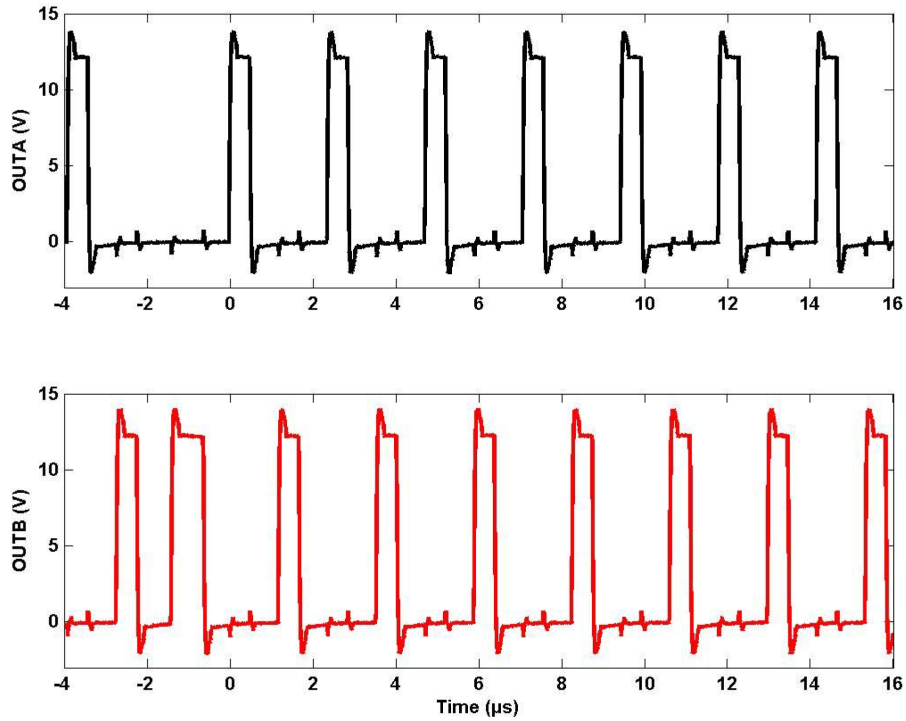

Figure 4. Double Pulse Event on OUTB from DUT4 at 86.3MeV•cm²/mg

The last column in Table 2 on page 4 represents soft-start hiccups during part operation. A representative example of these events is shown in Figure 5 on page 7 The switching activity on OUTA and OUTB stops and SS discharges to its minimum of about 0.4V and then begins to charge again with OUTA and OUTB resuming their switching activity after about 16ms. The soft-start voltage (green trace) when switching begins again is about 2.4V.

The counts for the Single Event Functional Interrupts (SEFI) that appear in Table 2 (column 5) are underestimates of the actual SEFI encountered in the irradiations. The reason for the undercounting is an error in the oscilloscope set-up that set the samples per captured trace to $5x10^7$ samples. This led to an excessively long data transfer time (approximately 6 seconds per capture) during which the oscilloscope was “blind” to another SEFI event.

Examination of the OUTA pulse width events reveals cases that capture the return to switching activity of the outputs as SS recovers from an SEFI. Such an event is shown in Figure 6. The switching of both outputs, OUTA and OUTB, begin at essentially minimum pulse width and slowly increase with time. Since these events are associated with the recovery from a soft-start SEFI, their count reflects the actual SEFI counts encountered in the irradiation. Post processing of the OUTA pulse width variation SET captures resulted in the counts of events similar to Figure 6 that are reported in Table 3 on page 8. The post processing counted only those events with pulses near minimum width. The counts are significantly higher than those of the SEFI represented by Table 2 by SS triggers. The zero counts agree in all cases including for LET equal to or less than 28.3MeV•cm²/mg.

For both forms of counting SEFI there are seemingly anomalous results for DUT4 and DUT5. DUT4 is the only device (of four) irradiated at 86.3MeV•cm²/mg that did not register SEFI, but DUT5 is the only device (of four) that registered SEFI with irradiation at 42.8MeV•cm²/mg. With no data or observations to provide an explanation the data must be viewed at face value.

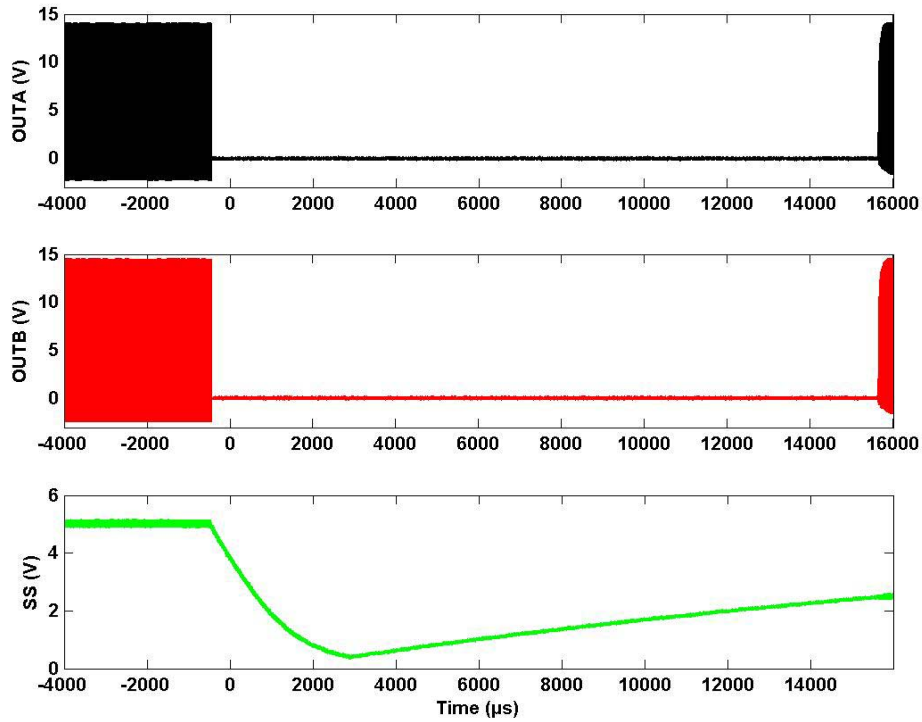

Figure 5. First SEFI for DUT2 Irradiated with 86.3MeV•cm^2/mg Gold

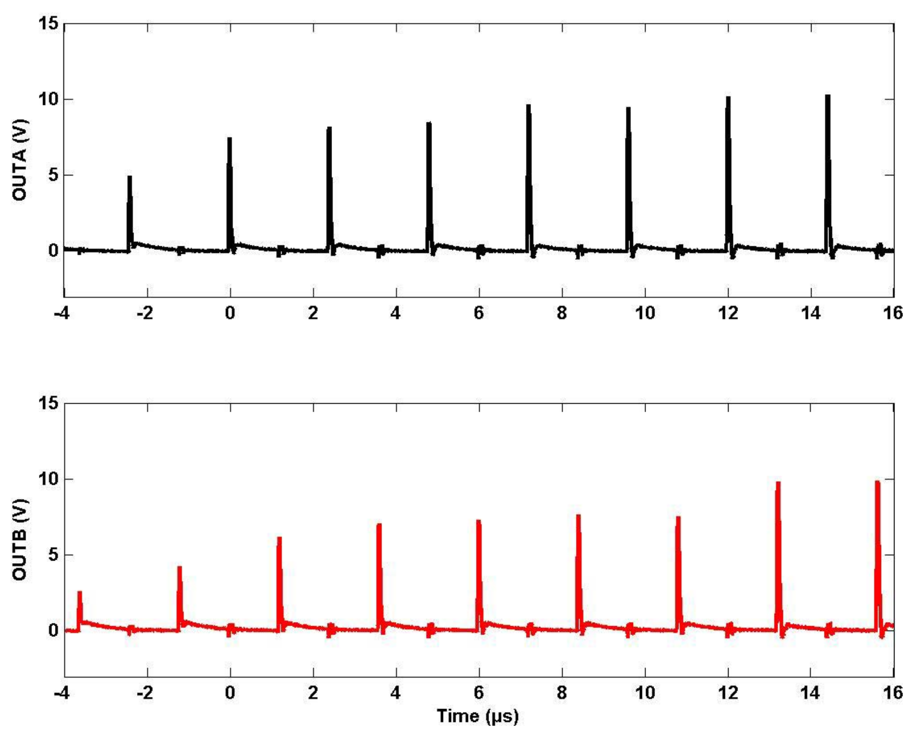

Figure 6. Recovery from SEFI Captured on OUTA and OUTB

Table 3. Extracted SS SEFI Counts from the OUTA Pulse Width SET Captures

LET, Species, and Fluence Normal Incidence ($MeV•cm^2/mg$)	Device	OUTA Events Apparent SEFI Recoveries	Nominal SEFI Cross Section (cm^2)
86.3, Au $2.0x10^6$ion/cm^2	DUT1	142	$7.1x10^{-5}$
	DUT2	144	$7.2x10^{-5}$
	DUT3	167	$8.4x10^{-5}$
	DUT4	0	0
42.8, Ag $2.0x10^6$ion/cm^2	DUT5	82	$4.1x10^{-5}$
	DUT6	0	0
	DUT7	0	0
	DUT8	0	0

Note: Only those captures exhibiting minimum width pulses indicative of SS restart were counted.

2. Discussion and Conclusions

The IS-1825AS was found to be immune to damaging SEE when run at V_{CC} = 20V and 24V, a case temperature of +125°C ±10°C, and irradiated with normal incidence gold ions for a surface LET of 86.3MeV•cm^2/mg. Four parts irradiated to $1x10^7$ion/cm^2 each showed no significant changes in the four monitor parameters as presented in Table 1 on page 3.

The IS-1825AS was found to have significant output pulse width disturbance due to ion irradiation. At the four LET levels tested (86.3, 42.8, 28.3, and 19.9MeV•cm^2/mg) output pulses ranging from dropped pulses (zero width) to full width pulses (50% duty cycle) were observed. In a few cases captured, one or the other output had a dropped pulse while the other output had a double pulse event.

In addition to the output SET described above, three of four parts showed a susceptibility to soft-start cycling SEFI when irradiated with gold for LET = 86.3MeV•cm^2/mg. SEFI events were also seen for one of four parts when irradiated with silver for LET = 42.8MeV•cm^3/mg.

3. Revision History

Date	Rev	Description
Mar 20, 2018	0.00	Initial Release

RENESAS

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Refer to "http://www.renesas.com/" for the latest and detailed information.

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