ISL71830SEH

Single Event Effects (SEE) Testing

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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 Burnout (SEB) and Single Event Gate Rupture (SEGR). 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 ISL71830SEH 16:1 analog multiplexer product for space applications.

Product Description

The ISL71830SEH discussed here is a 5V, 16:1 analog multiplexer fabricated in Intersil's proprietary P6SOI process. This product was designed with both Total Ionizing Dose (TID) and SEE in mind and has unique design provisions for mitigating effects of both radiation sources. The ISL71831SEH is a 32:1 multiplexer built of the same circuit blocks as the ISL71830SEH and is considered a circuit extension of the ISL71830SEH but is reported on separately.

Product Documentation

ISL71830SEH datasheet

Standard Microcircuit Drawing (SMD): 5962-15247

SEE Test Objectives

The ISL71830SEH was tested to determine its susceptibility to single event burnout and gate rupture (SEB as used here refers to either destructive ion effect) and to characterize its single event transient (SET) behavior. The SEB testing looked operating voltages at an LET of 60MeV*cm^2/mg that bounded a safe operating region. The SET testing looked for LET that have sufficient energy to generate an SET of a small size (±20mV) on the output of the multiplexer. Testing was performed on samples from the lot J69526.1 manufactured in Intersil's proprietary P6SOI process.

SEE Test Facility

Testing was performed at the Texas A&M University (TAMU) Cyclotron Institute heavy ion facility. This facility is coupled to a K500 super-conducting cyclotron, which is capable of generating a wide range of test particles with the various energy, flux and fluence levels needed for advanced radiation testing. Details on the test facility can be found on the TAMU Cyclotron website (http://cyclotron.tamu.edu/). Testing was carried out on December 15th and 16th of 2014 and March 20th of 2015.

SEE Test Set-up

SEE testing was carried out with the sample in an active configuration. A schematic of the ISL7830SEH SEE test fixture is shown in Figure 1. The test circuit configuration was set to address input 13 which, was consequently routed to the output. Switch 1 (SW1) allowed addressing to be selected between rail biasing (SW1 open) or logic threshold biasing (SW1 closed). The inputs were broken into three groupings (inputs 1 to 8 were tied to GND, input 13, and inputs 9 to 12 combined with inputs 14 to 16 and were tied to supply V_+). The splitting of the inputs into GND and V_+ allowed for bidirectional biasing of the unselected inputs

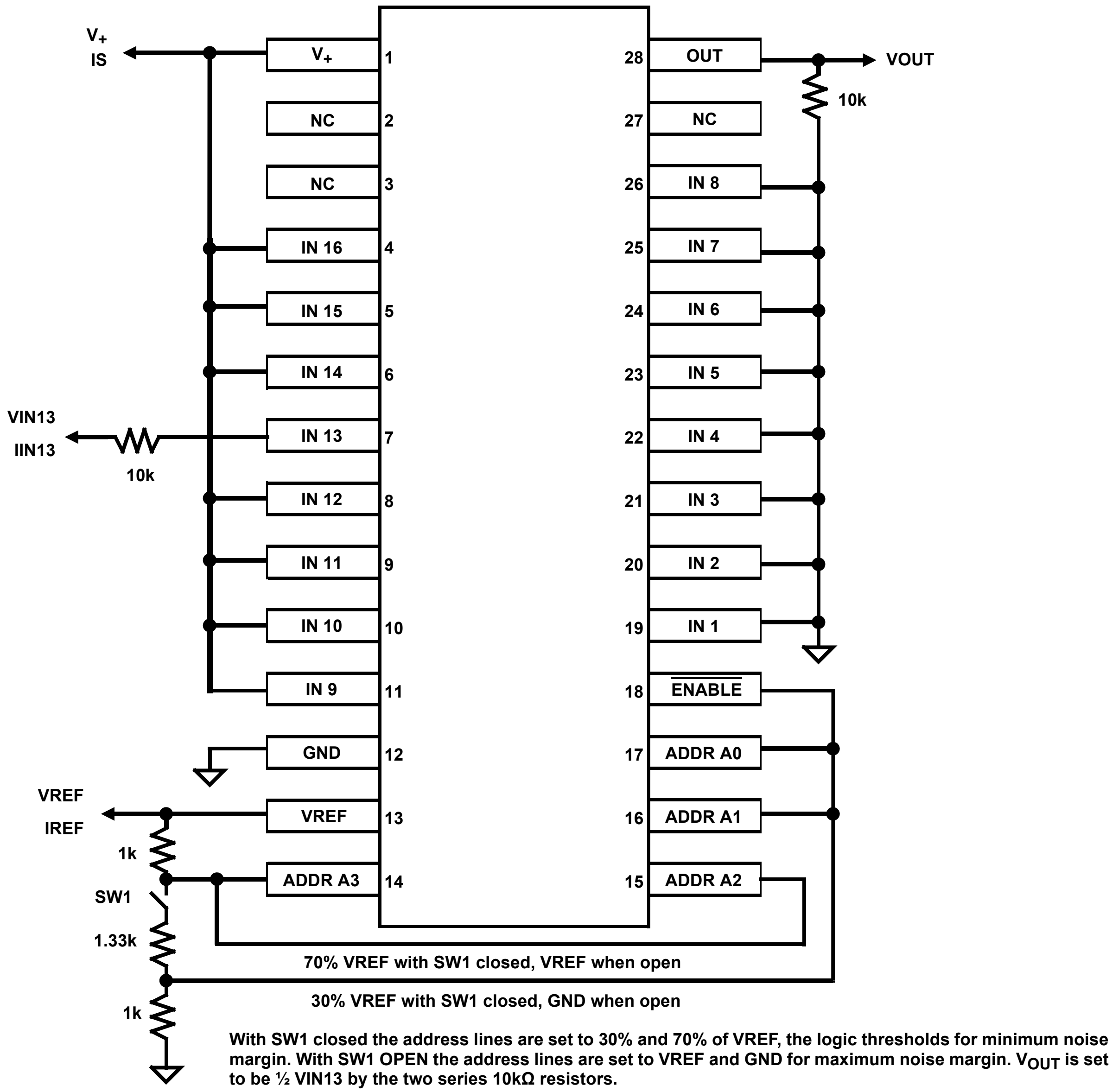

FIGURE 1. SCHEMATIC OF THE ISL71830SEH SEE TEST CIRCUIT

SEB Testing of the ISL71830SEH

The first set of SEB (destructive SEE) testing was carried out as summarized in Table 1. The output voltage along with the supply and reference currents were monitored for changes indicative of damage to the part. Four parts were tested in pairs through the condition sequence of increasing supply and input voltages. This SEB testing was done with Pr at 10° incidence for an effective surface LET = 60MeV*cm^2/mg. The Pr ions have a range into silicon of 110µm with a Bragg range of 37µm. This puts the LET Bragg peak well below the active device region and into the handle wafer of the SOI. Each irradiation was to an effective fluence of 5x10^6 ions/cm^2 with a case temperature of +125°C ±10°.

Significant changes in readings over the irradiations are indicated by shaded entry cells in Table 1. The SEB data indicates that ISL71830SEH at an LET = 60MeV*cm^2/mg did not suffer damage at supply and input voltage of 6.5V. DUT 4 did see a 12% increase in supply current at 6.5V, but this was not considered indicative a damage as the other increases noted constituted much larger increases. Catastrophic damage was noted on DUT2 at 6.75V but not on the other units at 6.75V and 7.0V. Safe operating range is so limited to 6.5V at an LET = 60MeV*cm^2/mg.

TABLE 1. ISL71830SEH SEB MONITOR PARAMETER TEST RESULTS (Note 1)

SEB TESTS AT LET = 60MeV*cm^2/mg					V_{OUT} (1%)		IS (10%)		IVREF (10%)	
	V_+ (V)	V_{REF} (V)	VIN13 (V)	APPROX. V_{OUT} (V)	PRE (V)	POST (V)	PRE (nA)	POST (nA)	PRE (nA)	POST (nA)
DUT 1	6.50	6.50	6.50	3.250	3.243	3.241	1323	1316	25	25
DUT 2					3.238	3.238	94.9	99	22	23
DUT 3					3.239	3.238	1708	1731	28	29
DUT 4					3.238	3.238	1995	2240	34	34
DUT 1	6.75	6.75	6.75	3.375	3.366	3.366	1463	1457	26	26
DUT 2					3.364	3.366	97	124µA	24	24
DUT 3					3.364	3.364	1918	1898	30	31
DUT 4					3.364	3.364	2490	2450	36	36
DUT 1	7.00	7.00	7.00	3.500	3.491	3.491	1603	1590	28	38
DUT 2					3.490	3.490	212µA	199µA	25	25
DUT 3					3.489	3.488	2100	2111	32	33
DUT 4					3.488	3.488	2700	2730	37	38

NOTE:

1. Samples were tested in pairs (DUT 1 and DUT 2 and DUT 3 and DUT 4) in the indicated sequence of conditions. Irradiation was with Pr at 10º incidence for effective LET = 60MeV*cm^2/mg with the case temperature at +125ºC ±10ºC and to a fluence of 5x10^6 ions/cm^2 for each test. Shaded entries indicate changes in excess of the change criteria at the column heads.

SET Testing of the ISL71830SEH

The objective of this SET testing was to look for SET disruptions on the output (pin 28, VOUT) of the operating ISL71830SEH. The biasing was arranged to provide addressing at the input logic thresholds of 70% and 30% of the V_{REF} (2.1V and 0.9V at V_{REF} = 3V). These settings provide minimal noise margin against SET events. The unselected inputs (1-12, and 14-16) were connected to one of the supply rail voltages while input 13 was connected to the positive supply through a 10kΩ resistor with another 10kΩ resistor from V_{OUT} to GND. This ensured a significant change in VOUT should an address change be induced or instantaneous connection to a rail be induced by an ion impact. A ±20mV trigger on VOUT was used to indicate and capture an SET. Testing began at LET = 86MeV*cm^2/mg and continued at LET = 43 and LET = 20MeV*cm^2/mg.

The results in Table 2 indicate that no SET of greater than 20mV deviation were generated for the testing run with LET = 20MeV*cm^2/mg and significantly fewer SET greater than 20mV were generated at LET = 43MeV*cm^2/mg as compared to LET = 86MeV*cm^2/mg.

The SET data was post processed to select out the twenty largest deviations (for both positive and negative extreme deviations) and the twenty longest durations (for both positive and negative extreme deviations) for plotting as in Figure 2 for the case of LET = 86MeV*cm^2/mg. Of the 80 possible SET not all are unique as the largest deviations are often also the longest durations.

From Figure 2 it can be seen that the SET observed at V_+ = 3V and LET = 86MeV*cm^2/mg were uniformly less than 75mV peak excursion and had decay time constants on the order of 5µs so that the SET essentially disappeared in 15µs from the SET initiation. The RC decay magnitudes appear to peak at about -50mV and +25mV. The RC decay time is dominated by the 700pF of the monitor cable and the 5kΩ of equivalent resistance driving VOUT to its nominal level.

Figure 3 displays the composite plots for the case of V_+ = 5.5V and LET = 86MeV*cm^2/mg. In these cases the peak excursions just exceed 100mV with slightly larger RC decay magnitudes than seen at V_+ = 3V. The slightly larger SET magnitudes are in line with the increase in V_+ from 3V to 5.5V so that the SET magnitudes seem linked to the supply rails as anticipated. Again the RC decay back to nominal VOUT is within 15µs.

Figure 4 displays the composite plots for the case of V_+ = 3V and LET = 43MeV*cm^2/mg. In these cases the peak excursions are under 50mV with RC decay magnitudes less than 25mV. In Figure 5 the trend toward larger SET with the higher V_+ of 5.5V is seen again, but the magnitudes are significantly less than seen at LET = 86MeV*cm^2/mg.

The trend toward smaller SET is completed at LET = 20MeV*cm^2/mg where no SET of greater than the ±20mV trigger criteria were captured. This does not imply a lack of SET but rather a limitation on the size of SET.

TABLE 2. TABLE FOR SET EXCEEDING ±20mV AT MINIMAL ADDRESSING CONDITIONS (Note 2)

TEST CONDITIONS: LET in MeV*cm^2/mg				SET COUNTS FOR ±20mV TRIGGER				
SW1	V_+, VIN13 (V)	V_{REF} (V)	APPROX. V_{OUT} (V)	DUT 1	DUT 2	DUT 3	DUT 4	CROSS SECTION (cm^2)
Au LET∠0º = 86								
CLOSED	3.0	3.0	1.50	296	410	–	288	8.28×10^{-5}
CLOSED	5.5	3.0	2.75	226	234	216	219	5.59×10^{-5}
Ag LET∠0º = 43								
CLOSED	3.0	3.0	1.50	29	19	11	8	4.19×10^{-6}
CLOSED	5.5	3.0	2.75	89	83	59	92	2.02×10^{-5}
Cu LET∠0º = 20								
CLOSED	3.0	3.0	1.50	0	0	–	–	$<1.25 \times 10^{-7}$
CLOSED	5.5	3.0	2.75	0	0	–	–	$<1.25 \times 10^{-7}$

NOTE:

2. SW1 = closed is logic thresholds. Each indicated irradiation was done to a fluence 4×10^6 ion/cm^2.

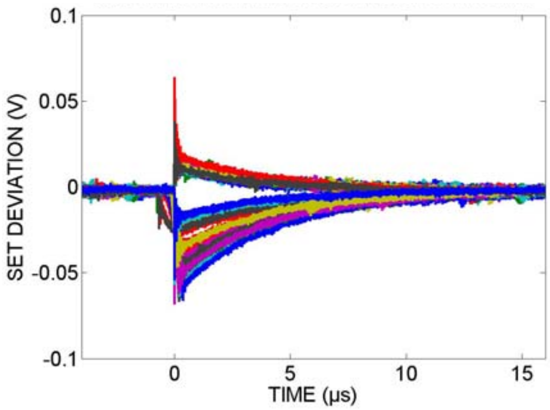

FIGURE 2A.

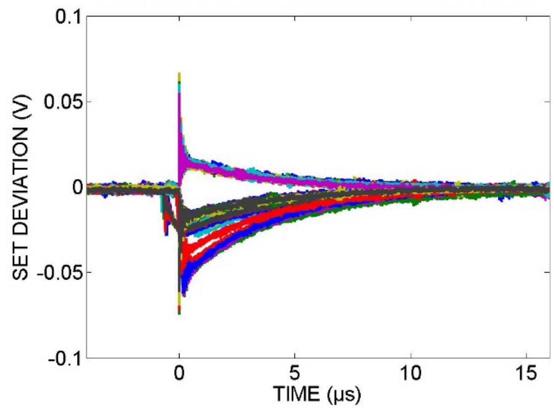

FIGURE 2B.

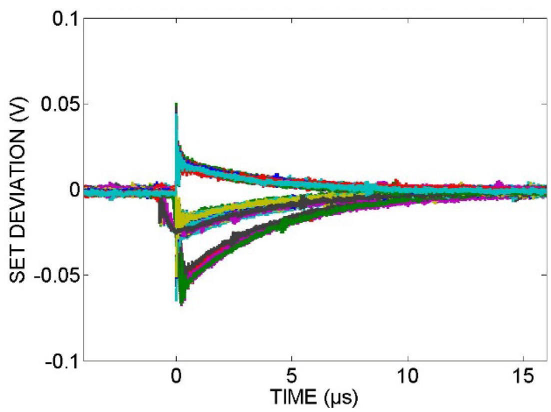

FIGURE 2C.

FIGURE 2. Composite plot of 20 largest and longest SET for both positive and negative deviations. DUT 1, 2 and 4 at LET = 86MeV*cm^2/mg and V_+ = 3V. DUT 3 had AC noise obliterating the SET indicative of a poor contact, so it was omitted.

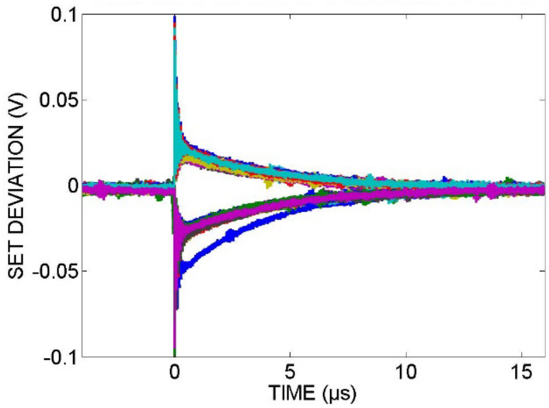

FIGURE 3A.

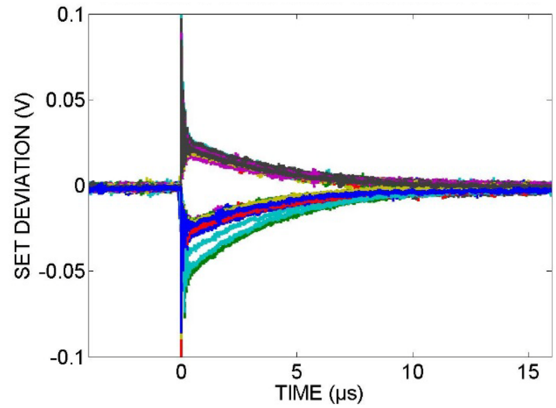

FIGURE 3B.

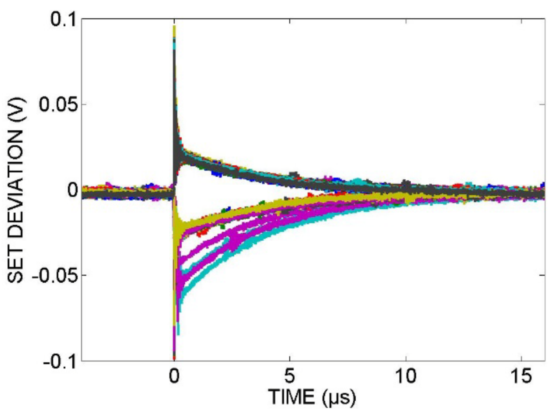

FIGURE 3C.

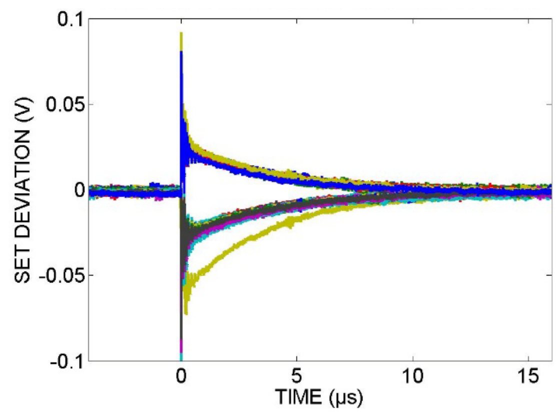

FIGURE 3D.

FIGURE 3. Composite plot of 20 largest and longest SET for both positive and negative deviations. DUT 1-4 AT LET = 86MeV*cm^2/mg and V_+ = 5.5V.

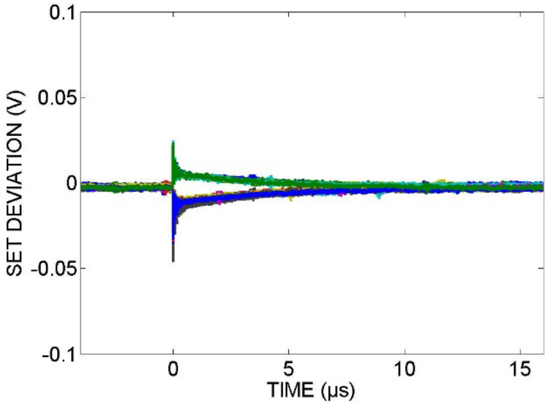

FIGURE 4A.

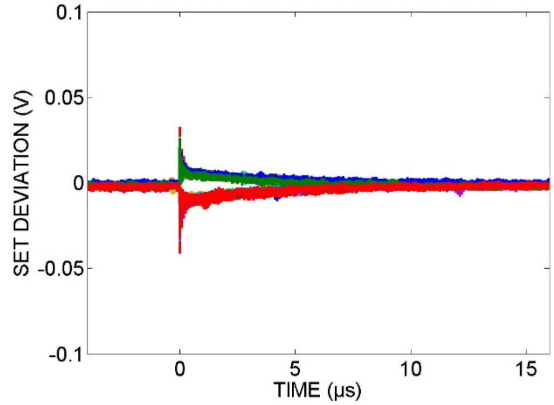

FIGURE 4B.

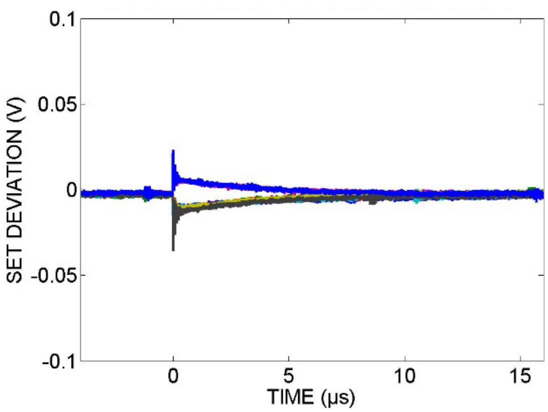

FIGURE 4C.

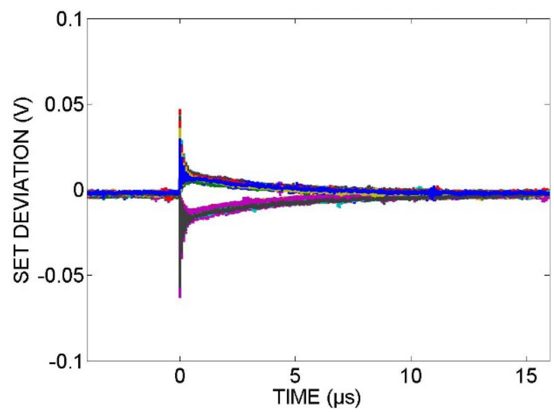

FIGURE 4D.

FIGURE 4. Composite plot of 20 largest and longest SET for both positive and negative deviations. DUT 1-4 at LET = 43MeV*cm^2/mg and V_+ = 3V.

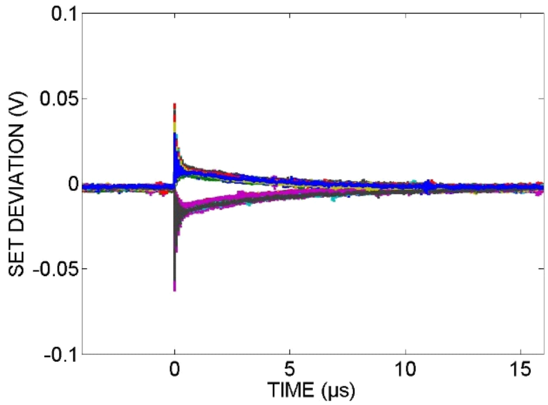

FIGURE 5A.

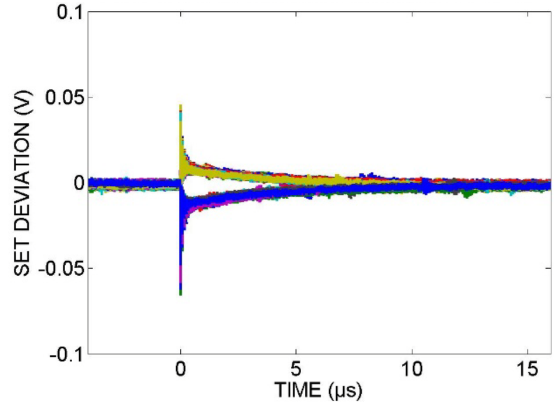

FIGURE 5B.

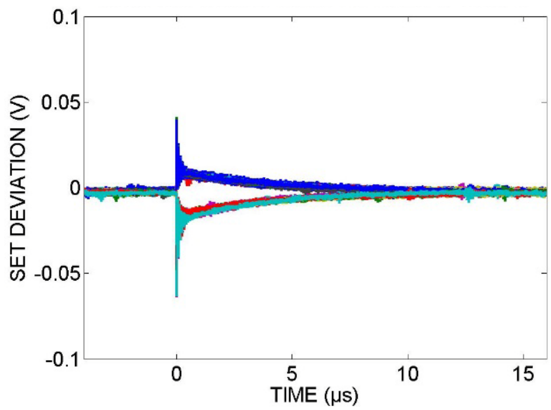

FIGURE 5C.

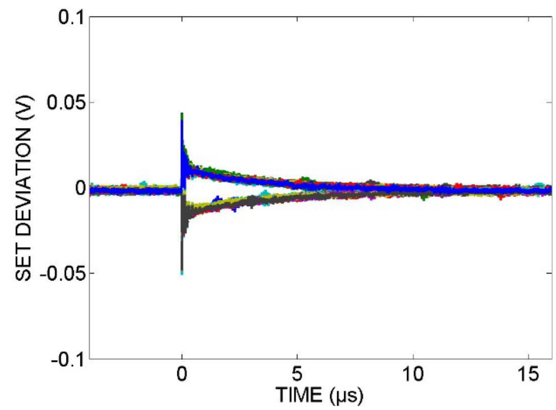

FIGURE 5D.

FIGURE 5. Composite plot of 20 largest and longest SET for both positive and negative deviations. DUT 1-4 at LET = 43MeV*cm^2/mg and V_+ = 5.5V.

Conclusions

No SEE damage (within 12% increase in supply current) was observed on the four units tested at 6.5V supply and inputs with ions of effective LET = 60MeV*cm^2/mg. The testing was done at +125°C case temperature. A unit registered catastrophic damage at 6.75V. Three units survived at 7.0V with no apparent changes due to irradiation there. It must be concluded that safe operation at effective LET = 60MeV*cm^2/mg is limited to 6.5V. Further testing is planned to look at the 6V to 6.8V range for better resolution on the limits of damaging SEE.

SET testing of the ISL71830SEH demonstrated only small SET (just over 100mV peak) at LET = 86MeV*cm^2/mg. At the 20mV trigger, the SET cross section was less than $1x10^{-4}$ cm^2 for LET = 86MeV*cm^2/mg. At LET = 43MeV*cm^2/mg the cross section for ±20mV events dropped to about $2x10^{-5}$ cm^2 with the maximum peak deviations under 50mV. At LET = 20MeV*cm^2/mg no SET reached the ±20mV trigger threshold corresponding to a nominal cross section of <$1.25x10^{-7}$ cm^2 for ±20mV events. In all cases the RC decay dominated by the 700pF of cable load on VOUT and the 10kΩ resistors to VIN13 and GND allowed the SET to die out in 15µs.

Extrapolating from the test conditions, the SET magnitudes toward the farthest rail could roughly double for signals nominally near either of the two rails, V_+ or GND. It is also reasonable to assume different recovery times for different VOUT loading and source resistance from the selected VINxx. For example, a 100pF load on VOUT and a 1kΩ source resistance should result in a SET recover in under 1µs.

SALES OFFICES

Renesas Electronics Corporation

http://www.renesas.com

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Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338

Colophon 7.0