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SINGLE EVENT EFFECT AND RADIATION DAMAGE RESULTS FOR CANDIDATE SPACECRAFT ELECTRONICS

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Abstract

We present both heavy ion and proton single event effect (SEE) and radiation damage ground test results for candidate spacecraft electronics. Devices tested include optocouplers, programmable devices, and fiber links.

I. Introduction

As spacecraft designers utilize increasing number of commercial and emerging technology devices in order to meet stringent spacecraft requirements such as volume, weight, power, cost and schedule, SEE and proton damage ground testing have become important tools for many spacecraft programs.

The objectives of this study were to determine heavy ion SEE sensitivities including the Linear Energy Transfer (LET) threshold (the minimum LET value to cause an effect at a fluence of 1x10^{7} particles/cm^{2}) and saturation cross sections, of candidate spacecraft electronics for Single Event Upset (SEU) and Single Event Latchup (SEL), proton SEE sensitivities, and proton damage sensitivities (ionizing and non-ionizing).

II. Test Techniques and Setup

A. Test Facilities

All tests were performed between February 1997 and February 1998. Heavy Ion experiments were conducted at the Brookhaven National Laboratories (BNL) Single Event Upset Test Facility (SEUTF). The SEUTF uses a tandem Tandem Van De Graaff accelerator, suitable for providing various ions and energies for testing. Test boards containing the device under test (DUT) are mounted inside a vacuum chamber. Testing was performed with LET values ranging from 1.1-120 MeV-cm^{2}/mg, fluences from 1x10^{5}-1x10^{7} particles/cm^{2}, and fluxes from 1x10^{2} -1x10^{5} particles/cm^{2}/sec, all depending on device sensitivity. Ions used are listed in Table 1. Intermediate LETs were obtained by changing the angle of incidence of the DUT to the ion beam, thus changing the path length of the ion through the DUT. Energies and LETs varied slightly due to multiple test dates over the calendar year.

Table 1: Test Heavy Ions

Facility	Ion	Energy, MeV	LET, MeV*cm2/mg	Range in Si
BNL	Cl-35	210	11.4	63.5
	Ti- 48	227	18.8	47.5
	Ni-58	278	26.2	41.9
	Br-79	286	37.2	39
	I-127	320	59.7	34
	Au-197	350	82.3	27.9

Table 2: Test Facilities and Particles

Facility	Particle
UCD	Proton
TRIUMF	Proton
LLUMC	Proton
IUCF	Proton
SPR	Neutron

Proton SEE and damage tests were performed at four facilities, the University of California at Davis (UCD) Crocker Nuclear Laboratory (CNL), TRI-University Meson Facility (TRIUMF), Loma Linda University Medical Center (LLUMC), and the Indiana University Cyclotron Facility (IUCF). Proton test energies ranged from 26.6 to 63 MeV at UCD, 50 to 500 MeV at TRIUMF, 51 MeV at LLUMC, and 54 to 197 MeV at IUCF. Typically, fluence was 1x10^{10}-1x10^{11} particles/cm^{2}, and flux was 1x10^{8} particles/cm^{2}/sec. Neutron damage tests were performed at Sandia National Laboratory Pulse Reactor Facility (SPR).

B. Test Method

Three SEE test modes were used, depending on the device under test (DUT) and the test objectives:

Dynamic - actively exercise a DUT during beam exposure while counting errors, generally by comparing DUT output with a reference device or other expected output. Devices may have several dynamic test modes, such as *Read/Write* or *Program-Only*, depending on their function. Clock speeds may also affect SEE results.

Static - load device prior to beam irradiation, then retrieve data post-run, counting errors

Biased (SEL only) - DUT is biased and clocked while I_{CC} (power consumption) is monitored for latch-up or other destructive conditions.

SEE DUTs were monitored for soft errors such as SEUs and hard errors such as SELs. Detailed descriptions of the types of errors observed will be noted in individual test results. Proton damage tests were preformed on biased devices with functionality and parametrics being measured either continuously during irradiation or after step irradiations (e.g., measurements every 10 krad(Si)).

Heavy ion SEE testing was performed with LET values ranging from 1.1-120. Proton test energies ranged from 26.6 MeV to 200 MeV.

All tests were performed at room temperature and nominal power supply voltages, unless otherwise noted.

III. Test Results and Discussion

Table 2 summarizes the devices tested and the test results, using the following conventions:

H = heavy ion test
P = proton test (SEE)
N = neutron test
SEU = SEU LET_{th} (MeV-cm^2/mg)
SEL = SEL LET_{th} (MeV-cm^2/mg)
SET = Single Event Transient
Destructive = Any destructive SEE LET_{th}
< = SEE observed at lowest tested LET
> = No SEE observed at highest tested LET
PD = Proton Damage (actually a mix of damage and ionizing dose)
TID = Total Ionizing Dose
σ = cross-section (cm^2/device, unless specified as cm^2/bit)
APL = Johns Hopkins Applied Physics Laboratory

All LET_{th}s discussed are in units of MeV*cm^2/mg; all σ_{sat}s discussed are in units of cm^2/device, unless otherwise noted.

Descriptions of test procedures for individual devices and results are summarized in Table 2. This paper is a summary of results, complete test reports are available online at:
http://flick.gsfc.nasa.gov/radhome.htm [1]

Table 3: Summary of Test Results

DEVICE	FUNCTION	MANUF.	RESULTS	NOTES
Memories				
5C1008FE-M	SRAMs 128k x 8 – 1 Meg	Austin	H: SEU < 3.38 SEL > 50	No difference between dynamic and static test runs. Proton data taken by APL.
AS5C512K8	SRAMs 512k x 8 – 4 Meg	Austin	H: SEU < 3.38 SEL > 50	No difference between dynamic and static test runs. Proton data taken by APL.
AS58C1001SF-15E	1Mbit EEPROM	Hitachi	H: Static: SEU > 37 Programming: SEU ~18.8 Block ~ 37 Stuck Bit ~37 SEL > 37	Tested in two modes, Static and Programming.
28C010TFE	128k x 8 EEPROM	SEI	H: Static: SEU > 69 Programming: SEU ~20 Block ~25 Stuck Bit 59.7 SEL > 69	Tested in two modes, Static and Programming. Hitachi die
57C256F-35	EEPROM	WSI	H: SEL < 18.8	Latch-up only test, SEL I_{CC} ~80mA
Luna ES Rev. C	4Mx4 DRAM	IBM	P: SEU Sensitive	Multiple error types noted including bit, pointer, and functional interrupt. See also [2].
67204EV-50	4K x 9 FIFO	Matra - TEMIC	H: Byte SEU ~3 Control SEU ~8 Mode Change SEU ~35	Three types of errors: bytes in error, control errors, and mode changes. The mode changed to high current cleared by reset pulse.

Programmable Devices				
A1280A	FPGA	Actel	P: SEU S-mod	See also [2]
22V10RPFE	PAL	SEI	H: SEU flip-flop < 3.38 SEU cominatorial ~10 SEL > 72.9	Three Lot Date Codes (LDCs) tested.
JT 22V10-10	PAL	Cypress	P: SEU on flip-flop.	Same die as 22V10RPFE.
Analog Devices				
OP400	OP Amp	PMI	H: SET ~20 SEL > 80	Minimum delta-V 0.25V
LM139	Analog Comparator	NSC	H: SET < 10 SEL > 37	Multiple transient sizes
1840RP	16 Channel Analog Mux	SEI	H: SEL > 110	
Ref - 43	Voltage Reference	Analog Devices	PD: Vref is sensitive parameter	See text
Optocouplers				
HCPL6651	Optocoupler	HP	P: SET PD: No degradation of CTR for the tested application (low fluence) H: SET < 0.03	See also [3] for details on optocoupler tests and results.
HCPL5631	Optocoupler	HP	P: SET N: Degradation of CTR	
4N48	Optocoupler	Optek	P: No SET PD:Degradation of CTR	
4N48	Optocoupler	Micropac	N: Degradation of CTR	
4N55	Optocoupler	HP	P: No SET	
6N140	Optocoupler	MP	P: No SET	
6N140A	Optocoupler	HP	P: No SET	
6N136	Optocoupler	Micropac	P: No SET	
P2824	Optocoupler	Hamamatsu	P: No SET PD: Degradation of CTR	Included in some Interpoint DC-DC converters.
HCPL5401	Optocoupler	HP	P: No SET	
66099	Optocoupler	MP	P: No SET	
66123	Optocoupler	MP	P: SET	
4N49	Optocoupler	Micropac	P: No SET	
66088	Optocoupler	Micropac	PD:No degradation of CTR for the tested application	
DC – DC Converters				
ASA2805S	DC - DC Converter	AA	H:SET<10, Destructive >37	SET was a voltage dropout of 10ms. Device response is dependent on loading.
ATW2805	DC - DC Converter	AA	H: SET <37, Destructive >37	SET was a voltage dropout of 10ms. Device response is dependent on loading.
AHF2812	DC - DC Converter	AA	H: SET <37, Destructive >37	SET was a voltage dropout of 10ms. Device response is dependent on loading.
7804	DC - DC Converter	AA	H: SET>37, Destructive >37	
MHF +2805S	DC - DC Converter	Interpoint	P: No SET PD: Functional failure N: Functional failure	Certain lots of these hybrids contain the P2824 Optocoupler from Hamamatsu
MHF +2812D	DC - DC Converter	Interpoint	P: No SET PD: Functional failure	Certain lots of these hybrids contain the P2824 Optocoupler from Hamamatsu
MHF +2815D	DC - DC Converter	Interpoint	P: No SET PD: Functional failure	Certain lots of these hybrids contain the P2824 Optocoupler from Hamamatsu
ADC				
AD976	16 bit ADC	Analog Devices	H: SEU < 3.38 SEL > 80	
7805LPRP	16-bit ADC	SEI	H: SEU < 1.45 SEL ~ 11.4	Latch-up protection worked.

Logic				
54ABT245	BiCMOS Logic Driver	NSC	H: SEU and SEL > 100	
54ABT245	BiCMOS Logic Driver	Phillips	H: SEU and SEL > 100	
SNJ54ABT245AJ	BiCMOS Logic Driver	TI	H: SEU and SEL > 100	
54LS03	Logic	TI	P: No SEUs observed	
54ALS05	Logic	TI	P: No SEUs observed	
54ALS1035	Logic	TI	P: No SEUs observed	
DAC				
MX7847TQ	DAC 12-bit	Maxim	H: SET ~ 10 SEL > 75	
DAC 08	DAC 8-bit	AD/PMI	PD: Iref, I_{IL} sensitive	Step irradiation 0, 30K
DAC 08	DAC 8-bit	Raytheon	PD: No degradation at 30K	
Hybrid				
Flashdisk 2 Mbit Card	Flashdisk PCMCIA	Sandisk	P: No SEUs observed	Static and dynamic modes.
Microprocessors				
MG80486DX266	Microprocessor	Intel	H: SEU ~ 5 Microlatch ~ 30 SEL ~ 30	Dynamic test with and without cache. Two types of SEUs, data and lock-up. Previous lots did not note SEL.
Mongoose V	RH Microprocessor	Synova	H: SEU > 83 (no cache), SEU ~40 (cache) SEL > 96	
Linear				
MIC4429AJB	Linear Driver	Micrel	H: SEU, SEL > 84.7	
Photonics				
OD880WJ	LED	OPTO Diode	N: Degradation of CTR	
SDL5601V1	Spectra Diode	LED	N: No degradation	
SEDS II	1773 1MHz F/O bus	SCI	P: SEU sensitive	Details provided in [4].
Data Transmission				
PFORX12 Receiver		Optical Networks Inc.	P: For results see text	
PFOTX12 Transmitter		Optical Networks Inc.	P: For results see text	
Miscellaneous				
FUGA 15	CMOS Image driver	C-Cam Tech.	H: SEL ~ 11.5	
UT 1553B RTI	UT 1553B RTI - non-RH product	UTMC	P: No SEUs observed w/ a limiting $\sigma < 6.67x10^{-10}$ cm^2/dev	

A. Memories

1. 5C1008FE-M and AS5C512K8 SRAMs

Both the Austin Semiconductor 1Mbit SRAM 5C1008FE-M and 4Mbit SRAM AS5C512K8 were tested with a 5V power supply voltage, in static and dynamic modes, with multiple test patterns. Minimal mode or device (per bit) variance was observed. For single bit errors, the LETth was <<3.38 (lowest tested). No SEL was observed up to an LET of 50 (highest tested). Double and triple bit errors were observed during testing. Figures 1 and 2 illustrate the test data for single and double bit errors.

2. EEPROM

a. AS58C1001SF-15E

This Hitachi 1Mbit EEPROM device (LDC 9646) was tested in both static and programming mode. No errors were noted in *static* mode. In *programming* mode, byte errors were observed beginning at an LET of 18.8, and blocks of memory location in error beginning at an LET of 37.1 (probable pointer error). A single hard error (a stuck bit) occurred at LET of 37. This error was mapped around for the rest of the test. Single hard errors were not observed in previous testing of the device [5].

b. 28C010TFE

Four SEI 128k x 8 EEPROMs were tested in both static and programming mode. Utilizing a Hitachi die, the results were similar to 2.a. above. No SEUs were observed during static mode irradiation. Errors were noted as follows during programming mode: byte errors at LET$_{th}$ ~ 20, block errors at LET$_{th}$ ~ 25, stuck bits errors at LET$_{th}$ ~59.7, with a SEL at LET$_{th}$ >69.

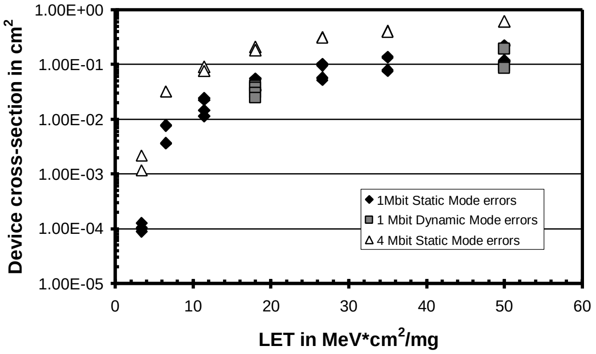

Figure 1: Single bit errors on Austin 1 and 4 Mbit SRAMs

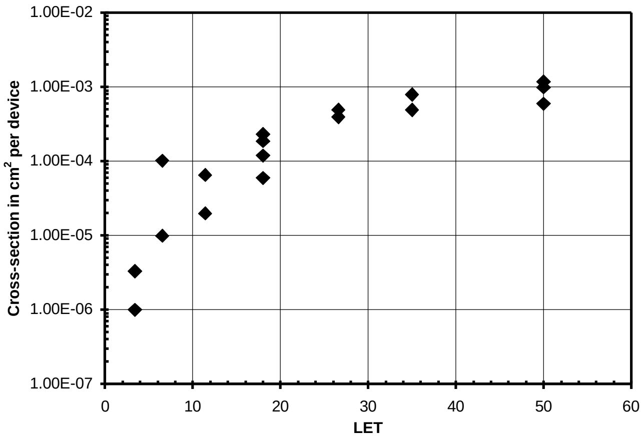

Figure 2: Double bit errors on Austin 1 Mbit SRAM.

c. 57C256F-35

Only latch-up tests were performed on two WSI EPROM DUTs (LDC 9718). LETth for SEL is < 18.8 with a SEL I_{CC} of ~80mA.

3. 67204EV-50 Matra FIFO

Three types of errors were observed in this 4Kx9 Matra – TEMIC FIFO device (LDC 9636): bytes in error, control errors, and mode changes. The mode change refers to a high current condition that was cleared by a reset pulse (possible test mode). LET_{th} was ~3 for SEU byte errors , ~8 for control SEU, and ~35 for Mode Change SEU.

4. Luna ES Rev.C IBM DRAMs

Proton irradiation was undertaken on stacks of these devices. Details are available in [2].

B. Programmable Devices

1. A1280A

This FPGA device from Actel experienced S-modules SEU sensitivity during proton irradiation. For more details see [2].

2. 22V10RPFE

Heavy ion tests were performed on six PAL devices from SEI. Samples were tested from three LDCs: XC349608493, XC34950484, and 002611202. Two outputs were monitored for D-register (or flip-flop) errors and combinatorial errors. The data rate for D-register testing was 1 MHz with a shift register of alternating 1's and 0's. The DUTs experienced flip-flop errors at $\text{LET}_{\text{th}} < 3.38$, ~10 for SEU combinatorial errors, and >72.9 for SEL.

3. JT 22V10-10

This PAL device from Cypress, LDC 9711, was tested in dynamic mode, 1 MHz, with a shift register of alternating 1's and 0's. During testing with 63 MeV protons, the device experienced SEUs in the flip-flops. Cross-section is ~$2\text{x}10^{-11}$ cm^2 per flip-flop. No upsets were observed in combinational logic gates. This is the same die as B.2.

C. Analog Devices

1. OP400

Heavy ion tests were performed on two PMI OP Amp DUTs from LDC 9621. SET errors were observed with an LET_{th} ~20, SEL was not seen up to an LET of 80. A minimum Δ-V of 0.25V was used to define a transient.

2. LM139

Multiple transient sizes were observed during heavy ion testing of this analog comparator device from NSC. Test results showed SET at LET < 10, SEL at LET > 37. This is an early test in a continuing investigation.

3. 1840RP

Heavy ion tests were performed on this 16-channel analog Mux from SEI. During testing, a +5 V signal is applied to the input and each of the 16 channels is selected at a frequency of 390.6 Hz revolving rate. The output is compared to a reference device. A window comparator monitored for SEUs, with a ± 10% margin (± 0.5 V in this case). SEUs were binned by duration: short < 10 μs, medium 10 μs to 100 μs, and long > 10 μs. No SEUs or SELs were seen on the 1840, up to a maximum tested LET of 110 [6].

4. REF - 43

This is a 2.5V bipolar voltage reference from Analog Devices. During proton damage tests using step irradiations, the DUTs experienced a sensitivity to the Vref parameter between 10 and 20 krad (Si). Figure 3 illustrates this.

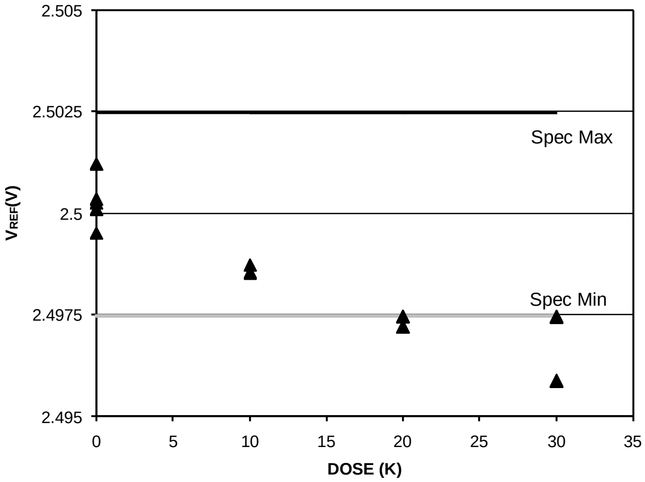

Figure 3: AD Ref-43 Proton damage sensitive parameter (Vref)

D. Optocouplers

Optocoupler performance in a radiation environment will be degraded in two ways: SETs can occur on the output and/or the current transfer ratio (CTR) can degrade [7,8,3]. CTR is the ratio of the input drive current to the output current. Optocoupler response to radiation will depend on the type of LED, phototransistor, and coupling medium. The response also depends on how the optocoupler is being used in the circuit. The results given below are not general results. We recommend application specific testing.

1. HCPL6651 Hewlett Packard (HP)

No degradation of CTR was observed during proton SET testing. Proton and heavy ion-induced SETs were observed for various angles and proton energies. A complete description is given in [8,3]. For this application, the proton cross section at 220 MeV was $1x10^{-8}$ cm^2 per optocoupler channel and did not vary with angle, while with irradiations with 70 MeV, the proton cross-section at 0 degrees was $1x10^{-8}$ cm^2 and at 90 degrees it was $1x10^{-7}$ cm^2. Limited heavy ion data are available in [3].

2. HCPL5631 HP

The device from Hewlett Packard was tested with bias off. SETs were noted during proton irradiation. Full information on test procedures and results are available [8,3].

3. 4N48 from multiple manufacturers

The Optek 4N48 device was tested for proton effects at UCD. No transients were observed with bias off. Complete technical data, along with test procedures and results are available [9]

The Micropac 4N48 optocoupler was tested for displacement damage effects induced by neutrons by irradiating them at SPR. The average CTR after each step irradiation is shown in Figure 4 for various input drive currents (output load was fixed). Degradations occurred only at the lowest drive currents for this application. All devices had degraded to <1% CTR after an exposure of $6x10^{12}$. No attempt has been made to characterize this optocoupler for single event transient effects [10].

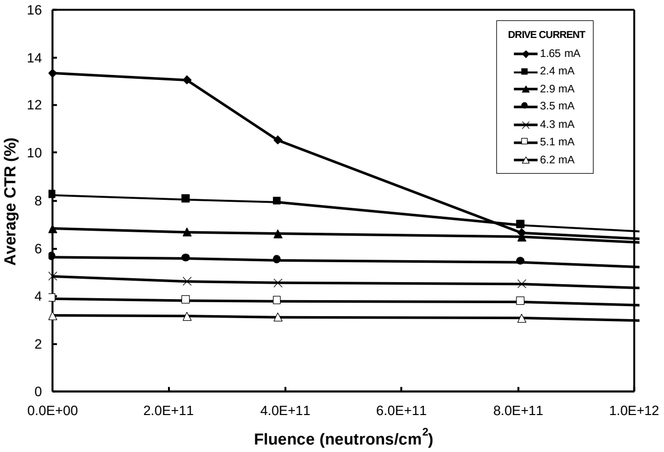

Figure 4. 1 MeV neutron irradiations of the Micropac 4N48 Optocoupler at SPR.

4. 4N55 HP

The HP 4N55 device was tested for proton SEE at UCD. No transients were observed with bias off. Complete technical data, along with test procedures and results are available [9]

5. STRV-1d Optocoupler Experiment Validation

Validation of an optocoupler spaceflight experiment that is to be flown on STRV-1d was done at TRIUMF using 58 MeV protons. Below we list each of the devices and the results of the validation testing. The minimum fluence was $2x10^{10}$.

Table 4: STRV-1d Proton Validation Results

Device	Results
Hewlett-Packard HCPL6651 no filter	SET observed No CTR degradation
Hewlett-Packard HCPL6651 passive filter	No SET observed No CTR degradation
Hewlett-Packard HCPL6651 active filter	No SET observed No CTR degradation
Micropac 6N140	No SET observed No CTR degradation
Hamamatsu P2824	No SET observed CTR degradation
Micropac 66123	SET observed No CTR degradation
Micropac 4N49	No SET observed No CTR degradation

Device	Results
Micropac 66099	No SET observed No CTR degradation

6. 6N140A

No SETs were observed during proton testing at UCD/CNL. This HP optocoupler, LDC 9707, was tested at a Vcc 4.5 with bias off [9].

7. 6N136

The Micropac 6N136 device was tested for proton effects at UCD. No transients were observed with bias off at 4.5 V. Complete technical data, along with test procedures and results are available [9].

8. P2824 – Hamamatsu optocoupler

Interpoint reported to us that the MHF+ series DC/DC converters with LDC 9603 and 9616 contain the Hamamatsu P2824 optocoupler. Other LDCs did not necessarily contain this optocoupler. We carried out proton and neutron step irradiations of the P2824 optocouplers at LLUMC, SPR, and IUCF.

The results from exposing six optocouplers with a 51.8 MeV proton beam at LLUMC are shown in Figure 5. Results from neutron exposures of six devices carried out at SPR are given in Figure 6. IUCF 195 MeV proton results for two devices are plotted in Figure 7. The pre-irradiation values are shown at zero fluence. Each plot shows the average CTR of the devices for various drive currents (fixed output load) versus accumulated fluence. The legend shows the drive currents. Complete technical data, along with test procedures and results, are available [10].

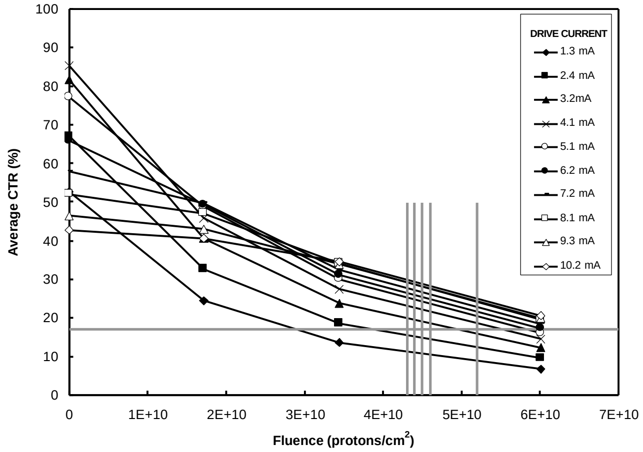

Figure 5: 51.8 MeV proton step irradiations of the P2824 Hamamatsu Optocoupler

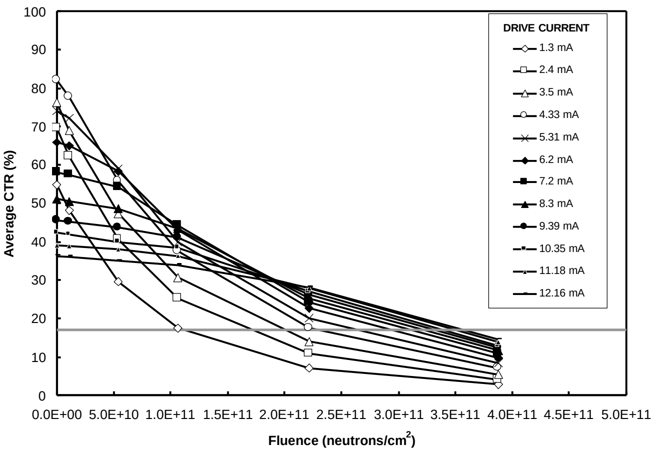

Figure 6: SPR 1 MeV equivalent neutron exposures of the P2824 Hamamatsu Optocoupler.

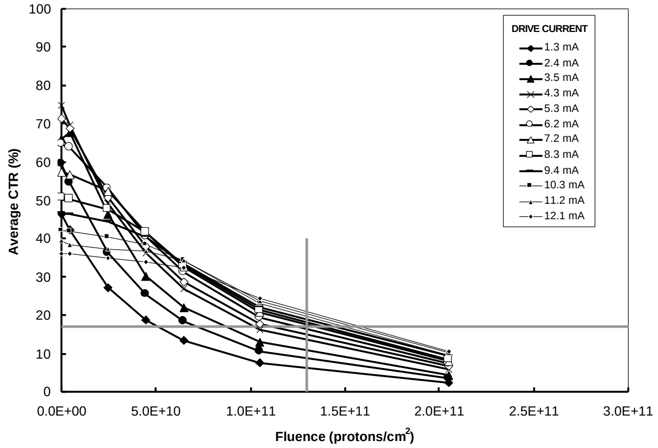

Figure 7: 195 MeV proton exposures of P2824 Hamamatsu Optocoupler at IUCF.

9. HCPL-5401

The HP 5401 optocoupler was tested for proton SEE at UCD. Transients (20-25 nsec) were observed with bias off (measured σ of $8.5\mathrm{x}10^{-8}$ cm^{2}per channel). Complete technical data, along with test procedures and results, are available [9].

10. 66088

Proton irradiations were carried out at UCD on Micropac's 66088. No degradation of CTR or SETs were observed for the application tested.

E. DC-DC Converters

1. ASA2805S, ATW2805, and AHF2812

Testing on non-RH DC-DC converters have provided some of the more interesting recent radiation results [11]. Issues with displacement damage with internal optocouplers in certain Interpoint devices are described in detail in a separate submission [3]. However, single event issues in certain Advanced Analog/Lambda converters may be of great interest to the system design. In these devices, a SET on an internal linear device or analog comparator is capable of causing the output voltage to “drop out”. Figure 8 is a sample of this phenomena induced by a heavy ion. Figure 9 illustrates the typical cross-section curve for an ASA2805 device with an output load of 12.5%. It was also determined that the output load had an effect on whether transients occurred (the lower the load the less sensitive the device). Table 5 shows this load effect for a given LET for several device types including some with internal resistors added as an attempt to filter the transients. More detail is provided in the test report [11]. Further tests are planned.

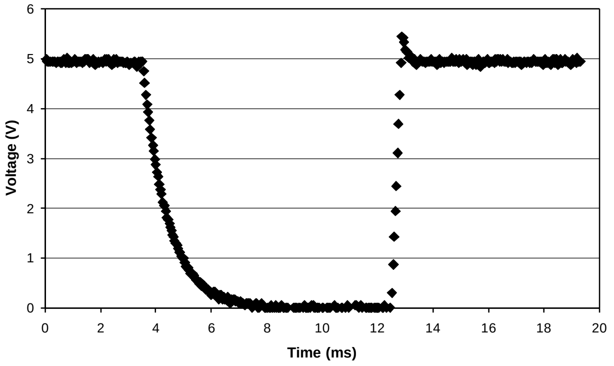

Figure 8: Single Event Transient from ASA2805

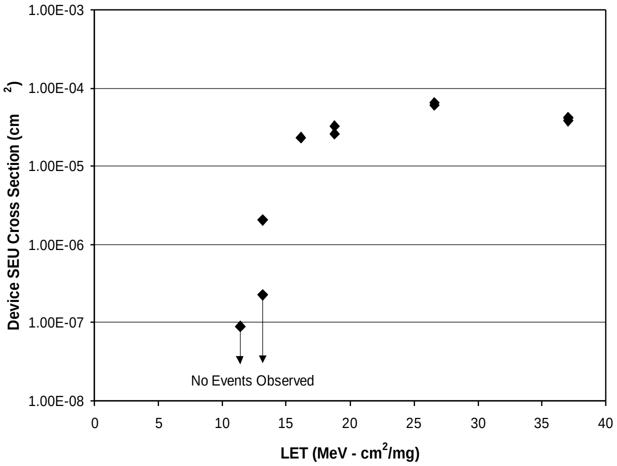

Figure 9: Advanced Analog ASA2805S/CH SN9726137-B

The ASA, ATW, and AHF series devices from Lambda/Advanced Analog could result in significant need for error detection and mitigation or correction techniques to correct for the 10 ms dropouts. In addition, knowledge of the actual load that will be used in the application is required. We would also recommend lot specific tests be performed to verify SET and destructive condition performance. AA/Lambda is attempting to correct this issue.

Table 5: Advanced Analog/Lambda SET Test Results

Device	Highest load level to not observe dropout at LET of 26.6
ASA2805	0%
ASA2805 w/180 ohm internal	< 20%
ASA2805 w/ 2K ohm internal	20% < level < 50%
ATW2805	70% < level < 83%
AHF2812	50% < level < 83%

2. AA/Lambda 7804

No SEEs were observed on the 7804 DC-DC Converter from Lambda-AA. The DUTs were tested up to an LET of 37. The SEE cross section is less than $1x10^{-7}$ cm^2 [11].

3. MHF +2805x, MHF+2812x, MHF+2815x

Proton, and neutron testing was performed on Interpoint MHF+ Series DC/DC converters at LLUMC, SPR and IUCF. Complete technical data, along with test procedures and results, are available [10].

The supply currents and output voltages as a function of 51.8 MeV proton fluence for five devices irradiated at LLUMC synchrotron are shown in Figures 10 (supply current) and 11 (output voltage). The data from proton exposures at LLUMC in Figure 11 show that the flight lot devices (LDC 9603) began to stop regulating at $4.4x10^{10}$ p/cm2. The LDC 9616 showed similar initial failure levels. Results of neutron step irradiations at SPR show that three of the five converters have onset failure between $1.1x10^{11}$ and $2.2x10^{11}$ n/cm^2. The other two converters show onset failure between $2.2x10^{11}$ and $3.8x10^{11}$ n/cm^2. IUCF 195 MeV proton results for four devices are consistent with the results from LLUMC.

During the 195 MeV proton irradiations at IUCF, we looked for "dropouts" (SETs) in the output voltage. No dropouts were observed for the MHF+2805S or the MHF+2805D.

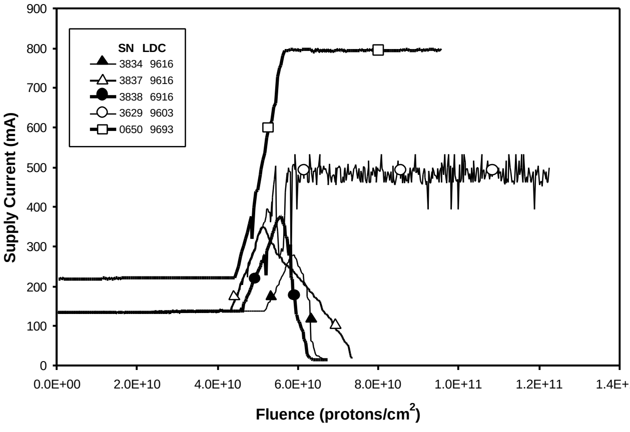

Figure 10: Continuous 51 MeV proton irradiations of interpoint MHF+ DC-DC converters at LLUMC.

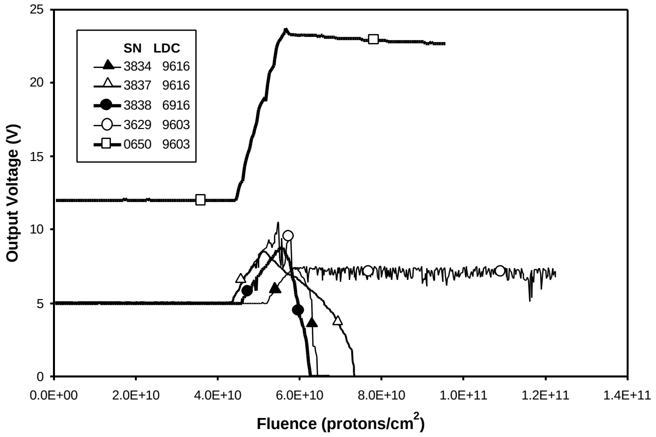

Figure 11: Continuous 51 MeV proton irradiations of interpoint MHF+ DC-DC converters at LLUMC.

F. ADC

1. AD976

This 16-bit ADC from Analog Devices, LDC 9723, was heavy ion tested. Test results show SEU at LET < 3.38 and SEL at LET > 80. Figure 12 illustrates this data set.

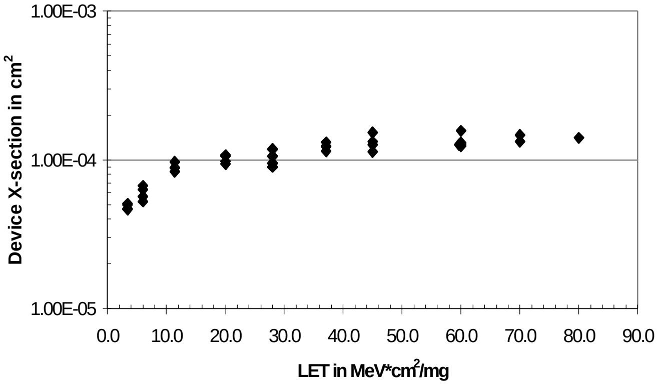

Figure 12: AD976 Heavy Ion Test Results

2. 7805LPRP

Heavy ion tests were performed on this 16-bit ADC from SEI, LDC 9435. It includes an older version of SEI's proprietary LPT™ circuit design to stop and recover from destructive/high-current latchup. Operational frequency was 40 kHz. The threshold for bit errors was below the lowest tested LET of 1.45, while the threshold for SEL/long errors was 11.4. The LPT™ circuitry worked adequately in providing overcurrent protection and power resetting the DUT [12].

G. Logic

1. 54ABT245

These BiCMOS logic drivers from NSC and Phillips were heavy ion tested. Test results showed SEU and SEL LET$_{th}$ >100 for both manufacturer's devices.

2. SNJ54ABT245AJ

This BiCMOS logic driver from TI was heavy ion tested. Test results showed SEU and SEL LET$_{th}$ >100.

3. 54LS03

No SEUs were observed during proton irradiation of this logic device from TI.

4. 54ALS05

No SEUs were observed during proton irradiation of this logic device from TI.

5. 54ALS1035

No SEUs were observed during proton irradiation of this logic device from TI.

H. DAC

1. MX7847TQ

This DAC 12-bit device from Maxim, LDC 9715, was heavy ion tested. Test results showed SET LET$_{th}$~10 and SEL >75.

2. Multiple vendors DAC 08

DAC08 8-bit D-to-A converters from two manufacturers, PMI and Raytheon, were step irradiated with 58 MeV protons. The Raytheon DAC08's, LDC 9622, were tested at 10 krad (Si) per step to a maximum of 30 krad. No degradation was noted on any parameter.

The DAC08 from PMI, LDC 9435, were tested at 30 krad (Si) per step. Radiation damage effects were noted. Figures 13 and 14 illustrate sensitive parameters. It is recommended that further testing at lower dose levels be undertaken if this device is considered for usage.

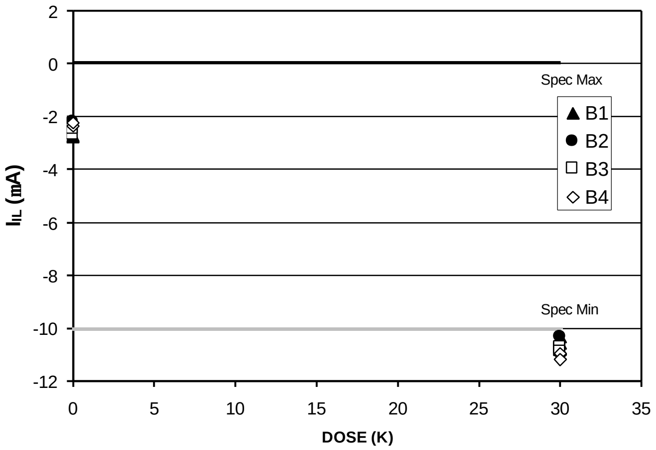

Figure 13: Sensitive parameter for PMI DAC08 LDC 9435

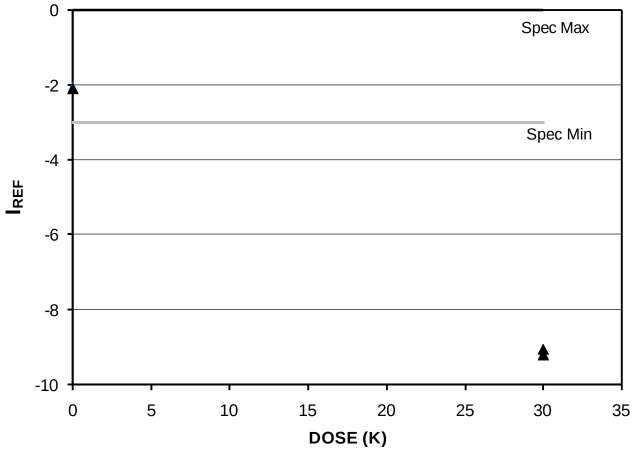

Figure 14: Sensitive parameter (I_{ref}) for PMI DAC08 LDC 9435

I. Hybrid Devices

1. Flashdisk 2 Mbit Card

The Flashdisk PCMCIA flash memory card is manufactured by Sandisk. Proton SEE tests were performed in static and read/write modes with alternating bytes test pattern of AA, 55, FF, 00H. No SEUs (data or control errors) were observed on any test run in either test mode. Hence, the limiting error cross-sections for protons is $< 1\text{x}10^{-11}\text{cm}^2$ per card. A total of 5.6 krads(Si) was placed on the candidate DUTs.

J. Microprocessors

1. MG80486DX266

SEU results for this Intel mocroprocessor were similar to previous 80486 testing [13]. Threshold LET for both data miscompare and device lockup SEUs was between 4.29 - 7.88 with and without the cache memory enabled. Both microlatchup and high-current SEL (destructive) conditions were noted. These conditions occurred at relatively high LETs of 26.6 and 37.3. Complete technical data, along with test procedures and results, are available [12].

2. Mongoose V

The Synova Mongoose V processor is a commercially-compatible R3000-based (LSI Logic's Ernie core) microprocessor with FPU, DRAM controller, and other peripheral functions integrated within. It is fabricated on Honeywell's hardened SOI process and performed very well under stringent heavy ion SEE testing. Testing was performed using worst case power supply voltages (4.2V and 5.5 V) in a dynamic mode with cache memory both enabled and disabled. Only fourteen SEUs with cache memory enabled occurred during the entire exposure of the three Mongoose processors to several different ion species. One anomaly occurred during an irradiation with cache disabled at an LET of 83. The source of this anomaly is unknown. The maximum tested LET at the surface of the die was 96. The integral particle fluence for all exposures that have LETs at the die surface of 37 or greater was 6.7×10^{8} particles/cm^{2}. All measured single event upset cross sections at all LETs were less than 1×10^{-7} cm^{2}/device. Complete technical data, along with test procedures and results, are available [14]

K. Linear

1. MIC4429AJB

This is a linear driver from Micrel, LDC 1D9309 . SEL was not observed, up to a maximum tested LET of 84.7 during heavy ion irradiation . No SET data were obtained.

L. Photonics

1. OD880WJ

Neutron tests were performed on this light-emitting diode (LED) from OPTO Diode. Degradation of CTR was observed. Figure 15 plots the output power as a function of the 1 MeV equivalent neutron fluence for the three LEDs at different drive currents. Note that Figure 15 utilizes step irradiations. The error bars show the spread in the output power among the devices. We recommend that one use the OPTO Diode Labs OD880WJ LED in space applications only after careful evaluation of the application against the space radiation environment [10].

2. Spectra Labs SDL5601V1

Six spectra diode devices from LED were tested. No degradation was observed for a 1 MeV neutron equivalent fluence of 8.0×10^{11} n/cm^{2}. We recommend that one use the Spectra Diode Labs SDL5601V1 in space applications only after careful evaluation of the application against the space radiation environment [10].

3. SEDS II Modules

Proton tests were performed on the SEDS II 1773, 1 MHz fiber optic transceiver from SCI. The SEDS II modules behaved similarly to the original SEDS I modules in that they were sensitive to bit errors induced by proton direct ionization. Full details are available in [4].

M. Data Transmission

1. PFORX12 Receiver and PFOTX12 Transmitter

Proton tests were performed on both the receiver and transmitter of this parallel fiber optic data bus (PFODB) physical electro-optical link from Optical Networks Inc. [15]. There are 2 cards per system (transmitter - T and receiver - R). We counted bit errors on individual channels (links) during testing as well as tracking power supply current consumption (damage effects).

All tests were performed with the board at normal incidence to the beam line and at the prime incident proton energy of 62.5 MeV at UCD.

During testing no bit errors were observed when 30 krads (Si) of protons was placed on either the transmitter or receiver portions of this PFODB. Icc also remained at nominal levels.

At ~85 krad(Si) exposure of the receiver, two items should be noted:

- Icc for the receiver test board had increased by 1.4 mA.
- Several "bursts" or clusters of bit errors occurred. This phenomenom is unexplained at this time, but only occurred while the device was being irradiated.

Devices appeared to remain functional after 100 krads (Si) exposure.

N. Miscellaneous

1. FUGA 15

Heavy ion SEL tests were performed on this CMOS image driver from C-Cam Tech. The LET threshold for SEL was between 11.4-12 [11].

2. UT 1553B RTI

Proton tests were performed on this UT 1553B RTI non-RH product from UTMC. No SEUs were observed for test runs of fluences of 1×10^{9} protons/cm^{2} [16].

IV. Summary

We have presented recent data from SEE and proton damage tests on mostly commercial devices. It is the authors' recommendation that this data be used with caution . We also highly recommend that lot testing be performed on any suspect or commercial device.

Additional data on programmable devices is available in Current Radiation Issues for Programmable Elements and Devices [17].

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