March 1, 1999

RT-SX PRODUCT RADIATION DATA REPORT

By J. J. Wang
Actel Corporation

I. SUMMARY

This report provides an up-to-date synopsis of radiation testing data for the RT-SX product family. Data were measured on the RT54SX16, which is a sixteen thousand gates part fabricated by MEC 0.5 µm technology. After the initial testing, Actel has continued to improve the radiation performance, both total dose and SEE, by materials, processing, and design changes. There are inventories of early products with reasonable radiation tolerance. We use revision numbers to differentiate these different materials. Table 1 summarizes the radiation data on different revisions. Rev 0 is the present available material in inventory. Rev 1 has higher total dose tolerance, and no JTAG SEU sensitivity. Rev 1 production silicon is at product testing stage. Rev 2 is still in the design stage. It will inherit Rev 1's merits, plus the SEU-hardened dedicated flip-flop (R-Cell). A memory bit made of C-modules can improve SEU tolerance. However, users have to place-and-route by themselves at this moment. In the future, macros will be added in the software tool to automate the "radiation-hardened" design. The JTAG upset issue is discussed in a separated report, which is included here as an appendix.

Table 1

	Rev 0	Rev 1	Rev 2 (Design Targets)
Total Dose (Icc)	50-80 krad(Si)	100 krad(Si)	>100 krad(Si)
R-Cell SEU Heavy Ion	LET_{th}=14 MeV-cm^2/mg X-section=2.5E-6 cm^2/FF	LET_{th}=14 MeV-cm^2/mg X-section=2.5E-6 cm^2/FF	LET_{th}>80 MeV-cm^2/mg
R-Cell SEU Proton	X-section=6.3E-15 cm^2/FF	X-section=6.3E-15 cm^2/FF	Immune
C-Mod SEU Heavy Ion	LET_{th}=43 MeV-cm^2/mg X-section=2E-8 cm^2/FF	LET_{th}=43 MeV-cm^2/mg X-section=2E-8 cm^2/FF	LET_{th}=43 MeV-cm^2/mg X-section=2E-8 cm^2/FF
C-Mod SEU Proton	Immune	Immune	Immune
Clock SEU	Immune (> 82)	Immune (> 82)	Immune
JTAG SEU	Need Clock Reset	Immune	Immune
SEL	Immune (> 82)	Immune (> 82)	Immune
SEDR	Immune (> 80)	Immune (> 80)	Immune

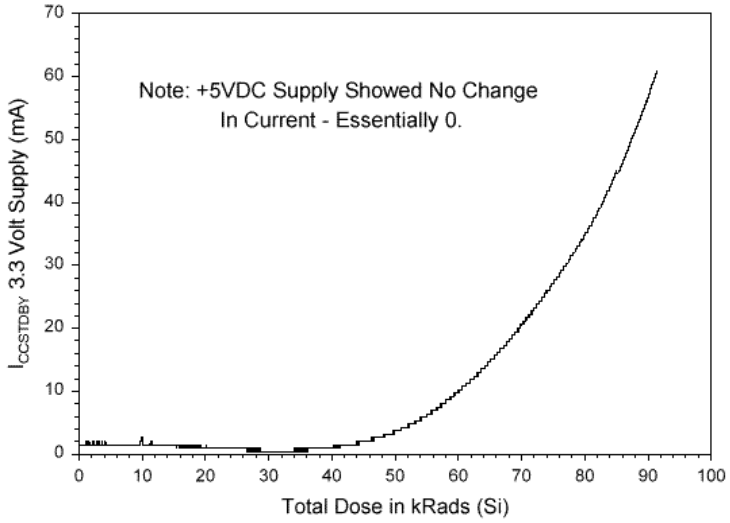

Figure 1 I_{DDSTBY} versus total dose of a typical Rev 0 device

II. TOTAL DOSE

The total dose tests were done in a quick turnaround mode. Only the static power supply current, I_{DDSTDY} (or I_{CC}) was measured since usually it is the limiting parameter for the total dose tolerance in the antifuse FPGA devices manufactured by Actel. Figure 1 shows the Rev 0 data. There are two power supplies for the device operation, 5 VDC for the I/O circuits and 3.3 VDC for the core logic modules. The total dose effect on the 3.3 VDC line dominates the total dose enhanced I_{DDSTDY} in a device. So only I_{DDSTDY} on the 3.3 V were measured and presented in this report. Using the specification of I_{DDSTDY} = 20 mA as the criterion, this typical Rev 0 device has the tolerance of approximately 65 krad(Si).

Figure 2 plots the I_{DDSTDY} versus total dose for a typical Rev 1 device. It shows Rev 1 device has the tolerance of approximately 100 krad(Si).

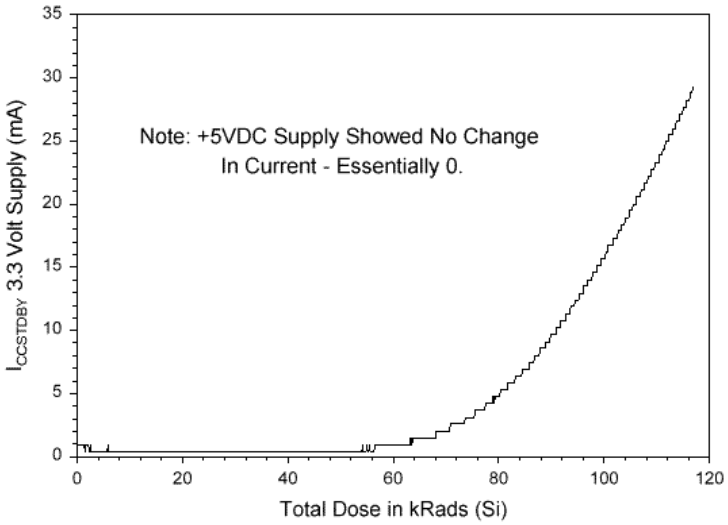

Figure 2 I_{DDSTBY} versus total dose of a typical Rev 1 device

III. SEU-HEAVY ION

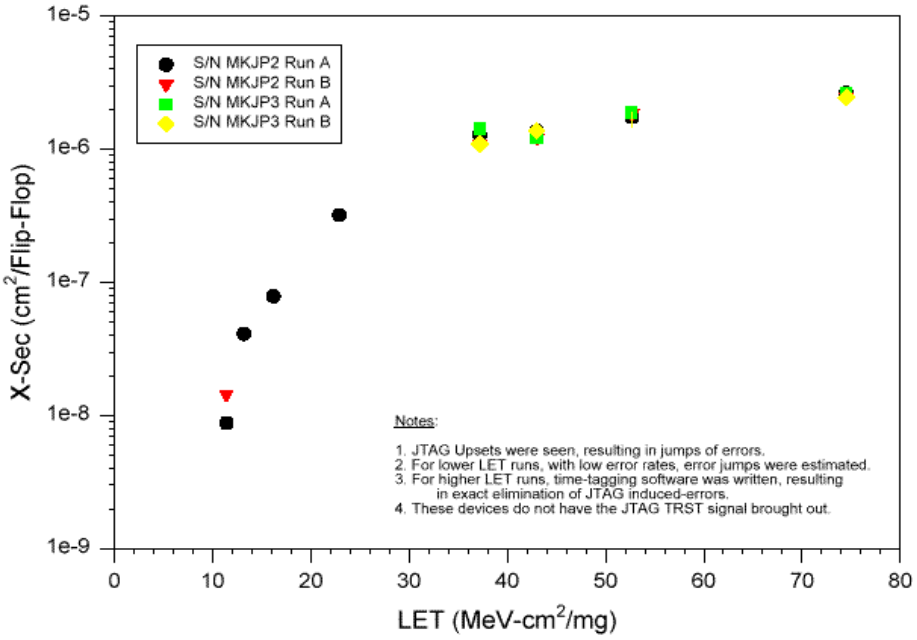

Figure 3 SEU cross-section versus LET of the R-cell in Rev 0

The BNL SEU facility was used to perform the heavy ion tests. Figure 3 shows the cross-section versus LET for R-cell flip-flop of two typical Rev 0 devices. The saturation cross-section is approximately 2.5 x 10^{-6} cm^{-2}. The threshold LET, defined at cross-section = 1% of saturation cross-section, is approximately 14 MeV-cm^2/mg. A shift-register was also designed by using two C-modules as a bit. The C-module SEU data is shown in Figure 4. Its saturation cross-section is approximately 2 x 10^{-8} cm^{-2}, and LET threshold is approximately 43 MeV-cm^2/mg.

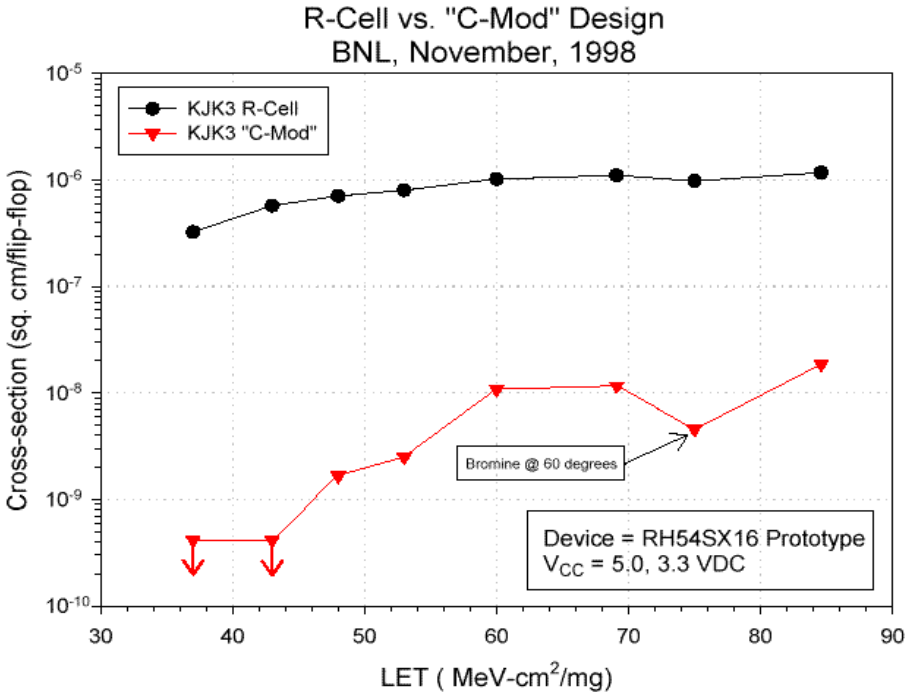

Figure 4 SEU cross-section versus LET of the C-Module flip-flop in Rev 0

IV. SEU-PROTON

The proton SEU of the R-Cell in a Rev 0 device was measured at the Indiana University Cyclotron Facility (IUCF). The proton energy was 193 MeV and the flux was set at approximately 1 x 10^9 p/cm^2/sec. The total fluence for each device was determined by the total dose response of the device and it's effect on the current draw; details for each device including bias are given in the table below. The device was irradiated normal to the beam.

Table 2 summarizes the device setup, irradiation conditions and results. Three devices were irradiated, two with worst-case biases of 4.5 V and 3.0 V and the other with a nominal biases of 5.0 V and 3.3 V. An estimate of the cross-sections can be computed as 6.3 x 10^{-15} cm^2/flip-flop at the worst-case voltage and as 3.1 x 10^{-15} cm^2/flip-flop at nominal supply voltages. There was no clock upset detected in any of the devices and no upsets were detected in the JTAG TAP controller.

Table 2

S/N	Lot	TCK	Bias (V)	Total Dose Krad(Si)	Upset Count	Fluence (p/cm^2)
MKJ1	Prototype D/C 9733	Off	4.5/3.0	75.4	2	1.2 x 10^{12}
MKJ2	Prototype D/C 9733	Off	4.5/3.0	75.4	4	1.2 x 10^{12}
MKJ3	Prototype	6 kHz	5.0/3.3	103.1	2	1.6 x 10^{12}

	D/C 9733					

V. SEL

SEL was tested simultaneously with SEU at BNL for heavy ion effects. None of the devices tested ever had a SEL. The bias was that V_{CCIO} = 5.5 V and V_{CORE} = 3.6 V. The LET was as high as 82.6 MeV-cm^2/mg.

VI. SEDR

SEDR was also tested at BNL for heavy ion effects. The DUTs were at a normal incidence to the beam with gold ion being used (LET = 82.6 MeV-cm^2/mg). Four devices were tested and all runs had a fluence of 10^7 ions/cm^2. The devices have a maximum rated voltage of V_{CCIO} = 5.5 V and V_{CORE} = 3.6 V. All antifuses are biased by V_{CORE}. The conditions for the runs were V_{CCIO} = 5.5 V and V_{CORE} = 4.0 V. The 'p' fuse was programmed for all devices, TCK was set to 6 kHz, and TDI was set to a logic '1'. No antifuse failures, i.e. SEDR, were ever detected during any run, showing a large positive margin and radiation-hard performance.

APPENDIX: SX JTAG Report - http://www.actel.com/products/devices/radhard/JTAG_SX.pdf