Single-Event Latchup Testing of the Fairchild Semiconductor NC7SZ74 UHS D-type Flip-Flop

J. A. Pellish[1], H. S. Kim[2], A. M. Phan[2], and A. J. Boutte[1]

NASA Goddard Space Flight Center
Code 561.4, Radiation Effects and Analysis Group
8800 Greenbelt RD
Greenbelt, MD 20771

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1: NASA Goddard Space Flight Center, Greenbelt, MD USA

2: MEI Technologies, Inc., Seabrook, MD USA

1. Purpose

The purpose of this testing is to characterize the Fairchild Semiconductor NC7SZ74 D-type flip flop (DFF) for single-event latchup (SEL) susceptibility. These data will be used for flight lot evaluation purposes.

2. Devices Tested

The NC7SZ74 is a single D-type CMOS Flip-Flop with preset and clear from Fairchild's Ultra High Speed Series of TinyLogic in the space saving US8 package. The device is fabricated with advanced CMOS technology to achieve ultra high speed with high output drive while maintaining low static power dissipation over a very broad VCC operating range. The device is specified to operate over the 1.65 V–5.5 V VCC range. The inputs and output are high impedance when VCC is 0V. Inputs tolerate voltages up to 7 V independent of VCC operating voltage. The output tolerates voltages above VCC in the 3-STATE condition. The signal level applied to the D input is transferred to the Q output during the positive going transition of the CLK pulse.

Ten (10) parts were provided for SEL testing. We prepared four parts for irradiation and kept the remaining pieces as spares. More information about the devices can be found in Table 1. The parts were prepared for testing by acid etching the plastic package and encapsulant away from the target die. The parts were then soldered to small copper circuit adapter boards for easy handling. These parts are fabricated in a bulk CMOS technology. Since we do not know the number of overlayers used in the fabrication processes, linear energy transfer calculations are determined based on the top-surface incident ion species and kinetic energy.

Table 1: Part Identification Information

Qty	Part Number	LDC	Source	Package
5	Flight: NC7SZ74K8X Generic: NC7SZ74	B1021AK	FairChild Semiconductor Corp.	8-lead US8

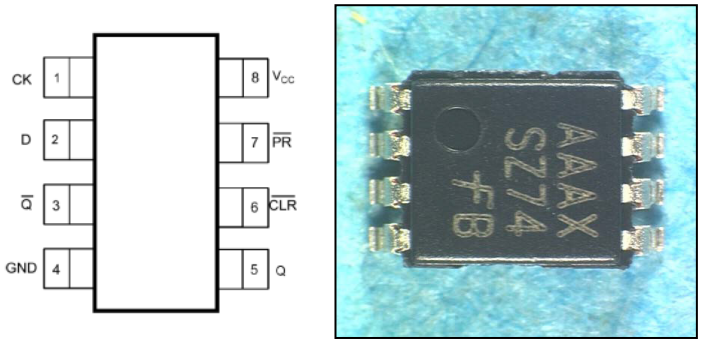
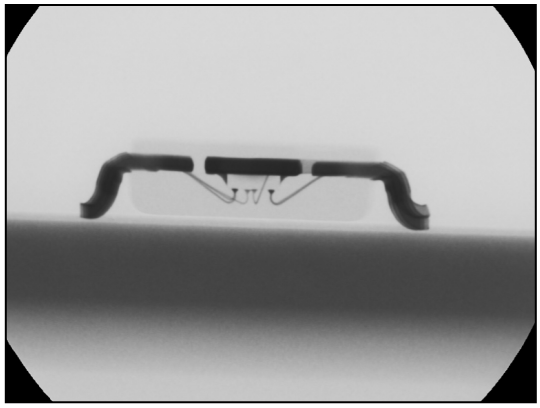
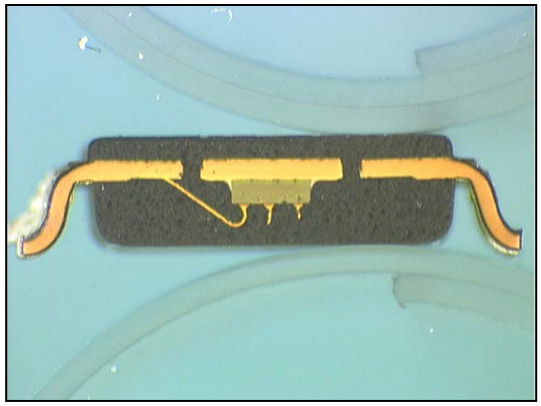


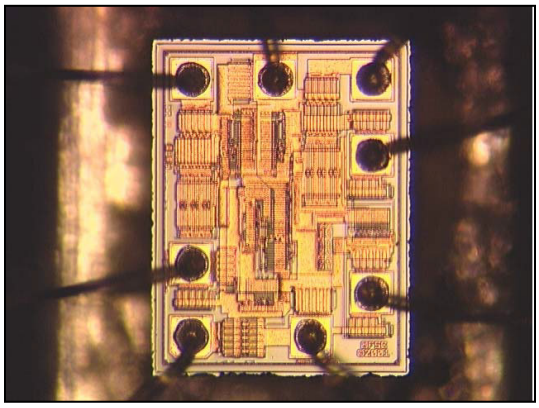
Figure 1: Pin diagram and corresponding package photo of NC7SZ74 DFF



(a)



(b)



(c)

Figure 2: NC7SZ74 package cross sectional images showing that the die is mounted upside down. (c) Shows a die photo after acid etching/decapsulation.

As shown in Figure 2, this die is oriented towards the bottom of the US8 package, which made mounting the components on the two-sided Cu-clad adapter board challenging. The parts essentially had to be soldered upside down in addition to making room for the thermistor.

3. Test Facility

Facility: Texas A&M University Radiation Effects Facility. Tune: 15 MeV/amu
Flux: 6×10^{4} to 1×10^{5} ions cm^{-2} s^{-1}
Fluence: All tests run to a fluence of 1×10^{7} cm^{-2} or until a high-current event is observed

Table II: Ion(s) Used for Device Irradiation

Ion	Energy (MeV)	Range in Silicon	Silicon LET (MeV cm^2/mg)
^{181}Ta	2076	119	77

Note that energy, range, and LET are calculated based on 1 mil aramica window and 30 mm of air prior to the silicon target.

4. Test Conditions and Error Modes

	NC7SZ74
Test Temperature	60° C
Operating Frequency	Static
Power Supply Voltage	+ 5 Vdc
Parameters of Interest	LET_{th}, temperature, supply voltage
SEE Conditions	Prolonged and self-sustained high-current state*

*Current limit set to 110% of absolute maximum rating.

5. Test Setup

The test circuits for all devices were built to model/approximate the intended application. However, these SEL tests were static with a DC bias on Vcc and inputs tied low (including the CLK). Decoupling capacitors were used on power lines.

The test setup is fairly simple, requiring only the digital I/O, relays, power supplies, and data logging equipment. The power supplies were located in the TAMU irradiation cave, while the data logging equipment were located in the high-bay. The digital I/O and relays on the test board allowed for rapid switching between parts to make testing more efficient – this includes power, Kapton heaters, and thermistors. The test board actually contained three different part types of which the NC7SZ74 is only one. A picture of the test board is shown in Figure 3.

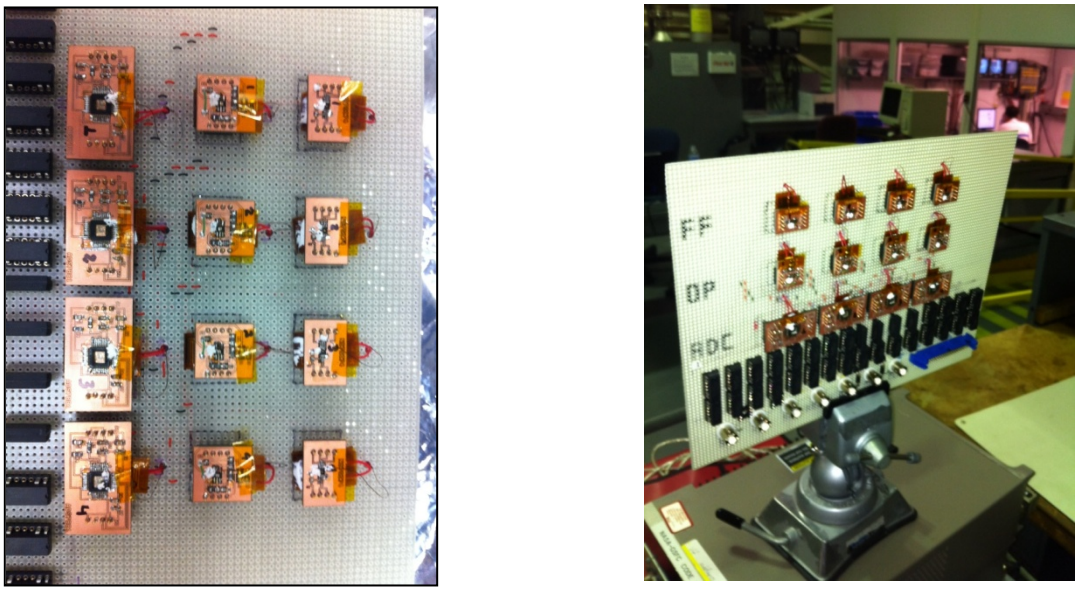


Figure 3: Test board configuration for the SEL test of the NC7SZ74 D flip-flop. The NC7SZ74 is located on the right row in the left image and the top row in the right image. The other parts on the test board were evaluated during the same run, but are not covered in this report.

6. Test Results

Many exposures were conducted, covering irradiations on four separate devices from the same manufacturing lot date code. None of the devices experienced a sustained high current state that required user-intervention to correct. In fact, no significant current spikes/jumps were observed at all. There was a slight increase in the current while the beam was incident on the components, but this is to expected based on charge generation in the substrate of a CMOS device. The data in Figure 4 are representative of all exposures conducted.

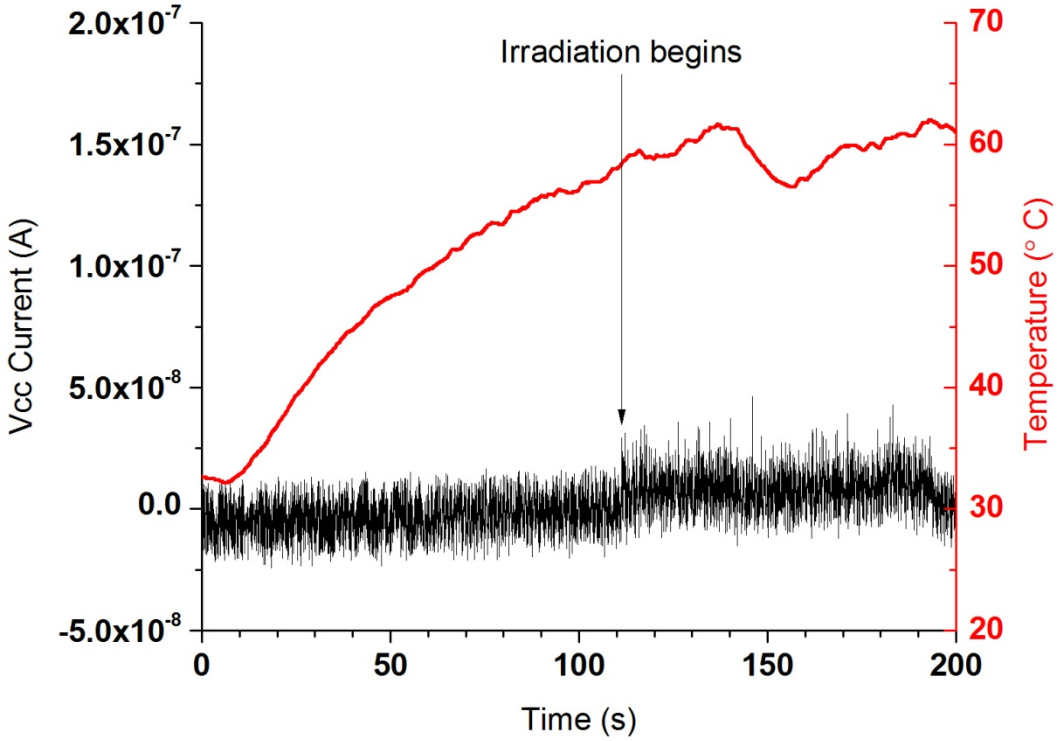


Figure 4: Example of a 94 s 15 MeV/amu Ta irradiation of the NC7SZ74 D flip-flop. Note absence of sustained high-current events.

7. Recommendation

This manufacturing lot of parts is recommended for use in NASA/GSFC spaceflight applications. This recommendation does not extend beyond the conditions tested and only applies to single-event latchup. No single-event upset or transient behavior is included.

8. URL for Device Data Sheet

- NC7SZ74: http://www.fairchildsemi.com/ds/NC/NC7SZ74.pdf

9. Run Log

Run	Type	DUT S/N	Temp (°C)	Tilt (deg)	Roll (deg)	Ion	Energy @ DUT (MeV/u)	Nominal LET (MeVcm2/mg)	Effective LET (MeVcm2/mg)	Range in Si (um)	Effective Range in Si (um)	Live Time (s)	Dose (rad(Si))	Avg Flux (1/cm2s)	Fluence (1/cm2)	Eff Fluence (1/cm2)	High-Current State or SEL	SEL XSEC (cm2)
1	FF	1	60	0	0	Ta	11.5	77	77	119	119	105.00	1.23E+04	9.50E+04	9.97E+06	9.97E+06	0	1.00E-07
2	FF	1	60	0	0	Ta	11.5	77	77	119	119	94.00	1.24E+04	1.06E+05	1.00E+07	1.00E+07	0	1.00E-07
3	FF	2	60	0	0	Ta	11.5	77	77	119	119	94.00	1.24E+04	1.07E+05	1.00E+07	1.00E+07	0	1.00E-07
4	FF	2	60	0	0	Ta	11.5	77	77	119	119	105.00	1.24E+04	9.53E+04	9.99E+06	9.99E+06	0	1.00E-07
5	FF	3	60	0	0	Ta	11.5	77	77	119	119	127.00	1.23E+04	7.86E+04	9.96E+06	9.96E+06	0	1.00E-07
6	FF	3	60	0	0	Ta	11.5	77	77	119	119	148.00	1.23E+04	6.75E+04	9.96E+06	9.96E+06	0	1.00E-07
7	FF	4	60	0	0	Ta	11.5	77	77	119	119	136.00	1.24E+04	7.38E+04	1.00E+07	1.00E+07	0	1.00E-07
8	FF	4	60	0	0	Ta	11.5	77	77	119	119	151.00	1.24E+04	6.59E+04	9.97E+06	9.97E+06	0	1.00E-07
9	FF	4	70	0	0	Ta	11.5	77	77	119	119	160.00	1.24E+04	6.23E+04	9.99E+06	9.99E+06	0	1.00E-07
24	FF	1	60	45	0	Ta	10.6	79	111	111	78	137.00	1.78E+04	1.03E+05	1.41E+07	9.98E+06	0	1.00E-07
25	FF	1	60	45	0	Ta	10.6	79	111	111	78	140.00	1.78E+04	1.01E+05	1.41E+07	9.99E+06	0	1.00E-07
28	FF	2	60	45	0	Ta	10.6	79	111	111	78	134.00	1.78E+04	1.06E+05	1.41E+07	1.00E+07	0	1.00E-07
29	FF	2	60	45	0	Ta	10.6	79	111	111	78	137.00	1.78E+04	1.03E+05	1.41E+07	1.00E+07	0	1.00E-07
32	FF	3	60	45	0	Ta	10.6	79	111	111	78	141.00	1.78E+04	1.00E+05	1.41E+07	1.00E+07	0	1.00E-07
33	FF	3	60	45	0	Ta	10.6	79	111	111	78	141.00	1.78E+04	1.00E+05	1.41E+07	1.00E+07	0	1.00E-07
36	FF	4	60	45	0	Ta	10.6	79	111	111	78	139.00	1.78E+04	1.02E+05	1.41E+07	9.97E+06	0	1.00E-07
37	FF	4	60	45	0	Ta	10.6	79	111	111	78	141.00	1.78E+04	1.00E+05	1.41E+07	9.98E+06	0	1.00E-07
38	FF	1	60	45	90	Ta	10.6	79	111	110	78	139.00	1.78E+04	1.02E+05	1.41E+07	1.00E+07	0	1.00E-07

39	FF	1	60	45	90	Ta	10.6	79	111	110	78	141.00	1.78E+04	1.00E+05	1.41E+07	9.98E+06	0	1.00E-07
40	FF	2	60	45	90	Ta	10.6	79	111	110	78	139.00	1.78E+04	1.02E+05	1.41E+07	1.00E+07	0	1.00E-07
41	FF	2	60	45	90	Ta	10.6	79	111	110	78	138.00	1.79E+04	1.03E+05	1.41E+07	1.00E+07	0	1.00E-07
42	FF	3	60	45	90	Ta	10.6	79	111	110	78	137.00	1.78E+04	1.03E+05	1.41E+07	9.99E+06	0	1.00E-07
43	FF	3	60	45	90	Ta	10.6	79	111	110	78	138.00	1.78E+04	1.02E+05	1.41E+07	9.99E+06	0	1.00E-07
44	FF	4	60	45	90	Ta	10.6	79	111	110	78	135.00	1.78E+04	1.05E+05	1.41E+07	9.99E+06	0	1.00E-07
45	FF	4	60	45	90	Ta	10.6	79	111	110	78	137.00	1.78E+04	1.03E+05	1.41E+07	9.99E+06	0	1.00E-07