Total Dose Test Report for Spansion 256M NOR Flash Nonvolatile Memory

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I. Introduction

The purpose of this test was to determine the susceptibility to total ionizing radiation dose (TID) of the Spansion 256M NOR flash nonvolatile memory (part number S29G256N90TFIR2, Lot Date Code 0539). This test was supported by the NASA Electronics Parts and Packaging (NEPP) Program.

II. Devices Tested

The Spansion 256M NOR Flash Memory is a non-volatile memory that uses a floating gate NOR cell, in 110 nm technology. It also provides a standard interface for pin and function drop-in compatibility. We believe these parts were burned-in before leaving the factory, so it is not possible to do a controlled experiment to look at burn-in effects. In any case, there is no plan to do our own burn-in. Detailed device information is provided in Table I. In this case, eight samples were irradiated, and there was also one unirradiated control device. The parts have a nominal 3.3 V power supply, plus an internal charge pump to generate higher voltages for writing and erasing.

Table I. Device information

Full Part Number	S29G256N90TFIR2
Manufacturer:	Spansion
Lot Date Code (LDC):	0606
Quantity Tested:	9
Serial Numbers of Control Sample:	9
Serial Numbers of Radiation Samples:	1,2, 3, 4, 5, 6,7,8
Part Function:	NOR Flash Memory
Part Technology:	CMOS
Case Markings:	Spansion S29G256N90TFIR2 0606 EF8
Package Style:	56 pin TSOP
Test Equipment:	Power Supply (+3.3V) Digital test board. Multimeters
Test Engineer:	M. Friendlich
Dose Levels (krad (Si)):	10, 20, 30, 50, 75, and 100krads(Si) continuing in 50krads (Si) steps until functional failure.
Target dose rate (rad (Si)/min):	1200-1800

III. Test Facility

Testing was at the Co-60 facility at GSFC, which is a room air source, where the pencils are raised up out of the floor, during exposures. Active dosimetry is performed, using air ionization probes. Testing is done in a step/stress manner, using a standard Pb/Al filter box. Dose rate typically varies slightly from one exposure to the next, up to 30 rads/s. Most exposures are near the maximum dose rate, as required by MIL-STD Test Method 1019.6. Time intervals for testing between exposures are also within the limits stated in 1019.6 (one hour after exposure to start electrical characterization, two hours to begin the next exposure). Parts were under DC bias during exposures, but not actively exercised.

IV. Test Procedure

The test devices were programmed with a checkerboard pattern (AA) during exposures, and biased at 3.6 V (3.3 V nominal power supply, plus 10%), but the devices were not actively exercised during exposures. Four parts were read (only) between exposures, to

look for problems related to the integrity of the individual bits. The other four parts were exercised between exposures—read, erased, and written into four different patterns. The patterns were checkerboard (AA), checkerboard complement (55), all ones, and all zeroes. In each of these tests, the entire memory is read, or erased, or programmed in one operation, with the commands entered manually. There is also a dynamic test mode, where each block is read, erased, and programmed, then the next block, and so on until the entire memory is completed. A block diagram of the test apparatus is shown in Fig. 1.

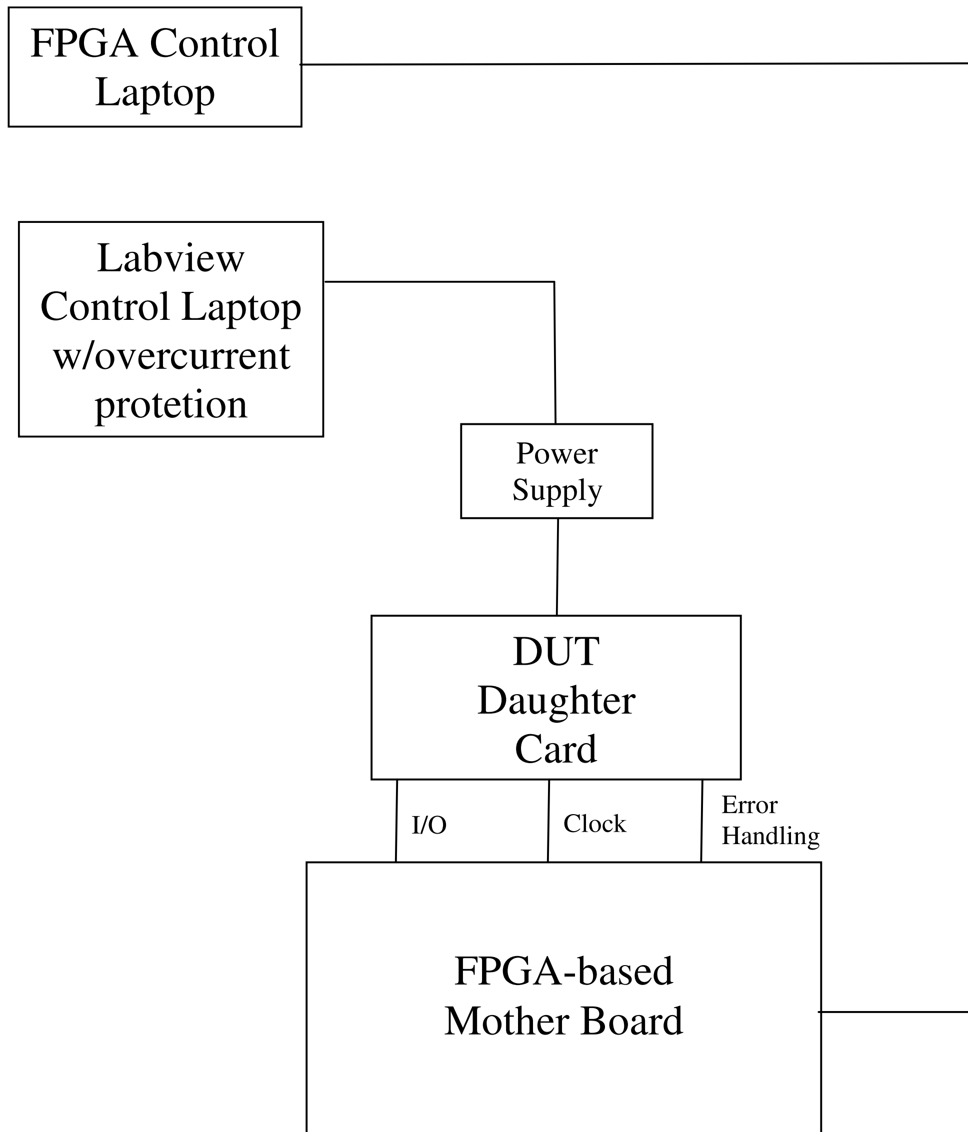

Fig. 1. Block diagram of the flash memory test apparatus.

V. Results

DUTs 1-4 were tested in read-only mode, while DUTs 5-8 were exercised in all the test patterns and the dynamic mode, as described above. At the 10 krad (SiO_2) exposure level, all samples functioned correctly in every test, with one exception. The exception was that DUT apparently had a bent lead, which caused the power supply to be applied to the wrong lead, which destroyed the device. This failure was not due to radiation, that we could tell. At the 20 krad (SiO_2) exposure level, DUTs 5-8 could not be exercised fully. The first erase operation took much longer than previous erases, but it was finally completed successfully. The write operation was not successful, producing a few hundred thousand to a few million errors, depending on the DUT. DUTs 1, 3, and 4 exercised in read-only mode, had no errors. Leakage current increased from 1 mA (for all devices) to 6 mA, at the end of the exposure, however. At the 30 krad (SiO_2) exposure level, only DUTs 1, 3, and 4 were tested, and leakage current increased to 54 mA. There were still no read errors on any of the three devices, however. At the 50 krad (SiO_2) exposure level, leakage current had increased to 368 mA, and the devices were so hot they were difficult to handle. They also had 8-26 million read errors. After errors were detected, we tried to reset the bits, but the erase and write circuits had both failed.

VI. Recommendations

In general, devices are categorized based on heavy ion test data into one of the four following categories:

Category 1: Recommended for usage in all NASA/GSFC spaceflight applications.
Category 2: Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.
Category 3: Recommended for usage in some NASA/GSFC spaceflight applications, but requires extensive mitigation techniques or hard failure recovery mode.
Category 4: Not recommended for usage in any NASA/GSFC spaceflight applications.
Research Test Vehicle: Please contact the P.I. before utilizing this device for spaceflight applications

The Spansion 256M NOR flash has not yet been characterized for Single Event Effects (SEE). It is expected to be Category 4, when more complete data is available.