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AUGUST 1979 LSI STATIC MEMORY TESTS.(U)

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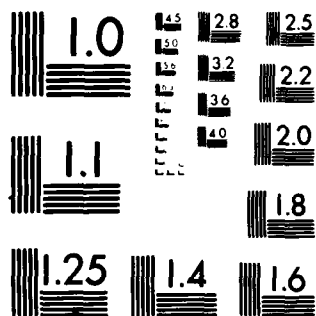
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August 1979 LSI Static Memory Tests

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Space Sciences Laboratory
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El Segundo, Calif. 90245

1 May 1981

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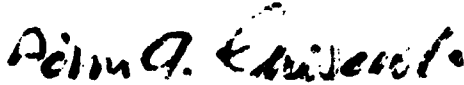
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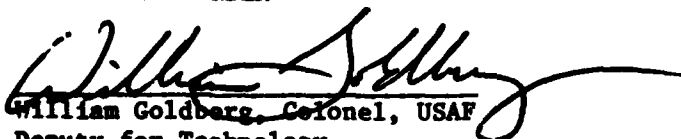
This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.


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21. ABSTRACT (Continue on reverse side if necessary and identify by block number) Several types of LSI static RAM's have been tested with heavy ions from the Lawrence Berkeley Laboratory 88C Cyclotron. Sufficient data were obtained to make the estimate that the latchup probability due to cosmic rays in space is approximately 0.02 per chip per year, for the MM54C929 RAM. The tests also showed that MWS5501 RAM's are essentially immune to cosmic-ray induced soft errors and latchup. Furthermore, it was found that the commercial version of the HM6508 is susceptible to both latchup and soft errors, while the various rad-hard			

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19. KEY WORDS (Continued)

(approx. 1×10 to the minus 7th power)

20. ABSTRACT (Continued)

versions of the same device are immune to cosmic-ray induced latchup and relatively hard against soft errors (5.1×10^{-7} per bit per day).

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August 1979 LSI Static Memory Tests

1. Test Objectives

There were two main objectives in the performance of these tests. The first was to establish the degree of susceptibility, if any, of various devices to heavy-ion induced latchup. In addition, the second objective was to obtain data needed to make a reasonable prediction of soft bit-error rates in the various devices, caused by cosmic rays in space. While time available for the tests did not permit a completely exhaustive study of the various devices, sufficient data were obtained to fulfill the first objective completely and to answer in large measure the questions implied by the second objective. Top priority in the test sequence was given to two versions of Harris 6508 RAM and the MM54C929 devices in the flat-pack version. Various other devices, listed in Table 1 were tested on a time-available basis.

2. Test Plan and Implementation

Detailed descriptions of the apparatus and test procedures have been given by Kolasinski et al. Table 1 contains a list of the part types tested together with a summary of their properties and types of tests performed.

The test plan was based on the a priori knowledge that a beam of 150 MeV krypton ions would cause some of the parts to latch and produce soft errors in most, if not all, of the devices. It was also assumed that to observe latchup and soft-errors, ionization charge in excess of a minimum amount must be produced within the sensitive volume of the device. Since the ionizing power of 150 MeV krypton is approximately 1.4 times higher than the maximum ionizing power of any cosmic rays encountered with

significant frequency in space, it was felt that the 150 MeV krypton beam represented a conservative upper bound for the severity of the effect of cosmic rays on the test components. Consequently, the plan called for an initial set of exposures to the krypton beam, with elimination from further testing of parts which either showed no soft errors and no latchup upon exposure at any angle to the beam, or whose threshold charge for the two effects could be deduced from the krypton runs by varying the exposure angle. Uneliminated parts would then be tested with available beams of argon and neon in a similar manner. Table 2 lists some of the relevant properties of the beams used in the testing.

Two sample boards, labelled Board V and Board VI, were designed and built to hold the test samples in the vacuum test chamber. Board V was for dual-inline plug-in parts with six positions reserved for HM6508's or electrically compatible parts and two positions used for HM6504's. On Board VI there were eight positions for soldering in the flat-pack version of MM54C929's or their equivalent. The various test memories were loaded and interrogated by a CD1802 microprocessor-based computer.

3. Results and Discussion

Table 3 is a summary of the test results. Due to lack of time, the devices on Board V could only be tested with krypton. Board VI was first exposed to krypton, then neon and finally to argon, in order to establish a lower bound for the ionizing power of particles capable of inducing latchup in the MM54C929 memories.

Five different groups of Harris 6508 RAM's were tested. These were obtained from the several programs which had requested test data.

Unfortunately, the traceability of some of these parts was somewhat dubious, so for purposes of the tests reported herein, labels based on priority in the test sequence, or on the source of the parts, have been appended as follows: P (prime interest), Q (questionable), R (RCA), S (Sandia) and T (tested by Rockwell). These letters appear in parentheses after the part number shown in Table 3. The parts which latch readily and presumably have large susceptibility to bit errors (Q and R in Table 3) have been identified as the standard commercial HM6508 RAM's. The other three groups (P, S and T in Table 3) represent rad-hard versions of HM6508 RAM's. Clearly they are also superior as far as performance in the presence of cosmic rays is concerned. Using estimates made by Pickell and Blandford, the expected bit-error rate in space for these parts should not exceed 1×10^{-7} errors per bit per day. Since the observed error-threshold energy appears close to that of the CD4061 RAM and since Sivo et al. predict an error rate of approximately 1×10^{-8} errors per bit per day for that memory, the HM6508 (P) error rate of 1×10^{-7} errors per bit per day can be regarded as a conservative estimate.

Apart from the MWS5501 SOS RAM which appears error-proof and the HM6508's discussed above, the value of the rest of the parts tested is questionable where space applications are concerned. The IM6508 while latchup proof, will show an error rate in space at least an order of magnitude higher than the above "good" 6508's. As far as the rest of the parts, they latch and are error-prone, so the risks of their use in space programs would appear rather high.

Time did not permit to obtain all the data needed to predict the expected latchup frequency in space. In case of the MM54C929 parts,

beams of neon (0.08 pC/ μ m ionization rate) and argon (0.15 pC/ μ M) did not cause latchup, whereas krypton, with ionization rate of 0.4 pC per micrometer did. There is reason to believe that the 0.15 pC per micrometer rate is close to the device threshold for latchup, since in previous tests argon had produced latchup in devices of this type. Using this value for threshold ionization rate, one can easily estimate the probability of MM54C929 latchup in space by assuming only iron-group nuclei can cause the effect. The flux of iron-group nuclei is approximately 1×10^{-3} particles/(m² sr MeV sec) at energies in the hundreds of MeV/nucleon. Actually the above value corresponds to the peak in the spectrum. By assuming the value to be constant at energies above 100 MeV one makes an error in the conservative direction. It turns out that only iron nuclei with energies below 8 MeV/nucleon are able to generate sufficient ionization charge, while in order to penetrate shielding thickness equivalent to 1 gm/cm² of aluminum, they must have energies above 100 MeV/nucleon. The shielding thus acts like a filter, allowing particles in a very narrow energy window to produce latchup. This window is approximately 3 MeV wide, so the flux of particles capable of producing latchup is

$$1 \times 10^{-3} \times 10^{-4} \times 4\pi \times 3 \times 86,400 \\ = 0.3 \text{ particles}/(\text{day cm}^2)$$

where it was assumed that all ions with energy below 15 MeV/nucleon will be capable of producing latchup, and that the cosmic-ray intensity is uniform over a solid angle of 4π . In the interest of conservatism, let

it be further assumed that these particles encounter the same area for latchup, regardless of the angle of incidence. Under those conditions, with the measured latchup cross-section of 2×10^{-4} cm, multiplied by the flux of 0.3 particles/(cm² day) gives the latchup rate of 6×10^{-5} latchups/(chip day) or 0.02 latchups/(chip year). In low-altitude polar orbits the daily flux encountered by a spacecraft is approximately 1/3 of that quoted above, so that the above latchup frequency should be reduced by the same factor.

4. Summary and Conclusions

In the tests described above, several types of electrically equivalent parts (Table 1) have been tested for susceptibility to latchup and soft bit errors. One of these, the MWS5501 appears completely immune to malfunctions of this type caused by heavy cosmic rays in space. The other RAMs tested, can be grouped into three classes as follows:

1. Highly immune to latchup and soft bit errors: HM6508 (P)
HM6508 (S), HM6508 (T)
2. Highly immune to latchup, susceptible to soft errors: IM6508
3. Susceptible to errors and latchup: HM6508 (Q), HM6508 (R),
MM54C929 and HM6504

Except for the MM54C929, time did not permit measurement of the degree of susceptibility of parts in category 2 and 3 above.

Extensive tests were performed on MM54C929 RAMs relating to both latchup and error susceptibility thresholds. The parts fit in category 3, with predicted latchup rates quoted in Section 3. Prediction of bit error rate in space requires knowledge of device parameters which presumably could be supplied by the manufacturer. At the time of this test effort, the above information was not available.

TABLE 1 Parts Tested in August 1979

Part #	Technology	Organization	Beam Types
MM54C929	CMOS/Si gate	1024 x 1	Kr, Ar, Ne
HM6508	CMOS/Si gate	1024 x 1	Kr
IM 6508	?	1024 x 1	Kr
HM6504	CMOS/Si gate	4096 x 1	Kr
MWS5501	SOS	1024 x 1	Kr

TABLE 2 Test Beam Properties

Particle Type	Energy (MeV)	Rate of Energy Loss in Si (MeV cm ² /gm)	Ionization Rate in Si (pC/μM)
Kr	150	40,000	0.41
Fe*	112	29,000	0.30
Ar	172	14,700	0.15
Ne	43	7800	0.08

*Quoted for comparison only--no test beam available

TABLE 3 Summary of Test Results

Part #	Beam	Response	Latch X-sect (cm ²)	Bit-error X-sect (cm ²)
MWS5501	Kr	None	0	0
HM6508 (P)	Kr	Errors	0	6.5×10^{-4}
HM6508 (Q)	Kr	Errors/latch	1.6×10^{-4}	1×10^{-2}
HM6508 (R)	Kr	Latch; errors?	$> 2 \times 10^{-5}$	?
HM6508 (S)	Kr	Errors	0	1.3×10^{-3}
HM 6508 (T)	Kr	Errors	0	7.7×10^{-4}
IM6508	Kr	Errors	0	3.4×10^{-3}
HM6504	Kr	Errors; latch	1×10^{-3}	3.1×10^{-2}
MM54C929 (A) *	Kr, Ar, Ne	Errors; latch	2.2×10^{-4}	5.4×10^{-3}
MM54C929 (B) *	Kr, Ar, Ne	Errors; latch	6×10^{-4}	7×10^{-3}
MM54C929 (C) *	Kr, Ar, Ne	Errors; latch	4×10^{-4}	7×10^{-3}

* A - standard part

B - irradiated with 10^{13} neutrons/cm²

C - irradiated with 10^{14} neutrons/cm²

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LABORATORY OPERATIONS

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