Radiation Evaluation of the 80C186 16-Bit Microprocessor Utilizing a Novel Technique for In-Situ Electrical Biasing and Characterization

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ABSTRACT

Radiation data for the 80C186 16-bit microprocessor for two manufacturers is presented. An in-circuit emulator was used to dynamically bias and functionally test the microprocessors. Data show failure levels that differ by more than a factor' of ten.

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ABSTRACT

Radiation characterization data for the 80C 186 16-bit microprocessor for two manufacturers is presented. A novel approach using an **in-circuit** emulator to carry out in-situ dynamic biasing and functional testing was used. Data from these tests data show parametric failure levels that differ by more than a factor of 10 between the two manufacturer's devices.

INTRODUCTION

The 80C 18616 bit microprocessor has been used in spacecraft applications for ninny years [1]. Uses generally include embedded applications where the 80C186 is controlling spacecraft communication, attitude control and other housekeeping duties. Because of the 80C 186' S low cost and mature development tool and programming base, it is still the microprocessor of choice for many space applications.

Previous tests have shown that the radiation failure level of the Intel version of this device is approximately 15 krad(Si) [2-8]. Typically, existing radiation test data is based on static radiation biases or fairly simple clocking arrangements that do not fully exercise the. microprocessor circuit or involve very complicated and/or expensive test setups [2- 12].

Another limitation of conventional microprocessor testing approaches is the cost of developing functional vectors to adequately perform functional tests on automatic test equipment. In this paper, wc introduce a novel, low cost method of generating lest vector sequences for in-situ operation and electrical characterization of a microprocessor utilizing an in-circuit emulator. Using an in-circuit emulator to operate a microprocessor during radiation allows a much wider degree of freedom and control over the processor under test than more conventional methods. An in-circuit emulator gives the user complete control over the operation of the microprocessor allowing the user to bias a very complicated circuit in a precise way much more affordably. This approach could easily be utilized on more advanced microprocessors such as: 80C386, 80C486 and Pentium as there Several in-circuit emulation producers for' the..w microprocessors.

EXPERIMENTAL APPROACH

A ^{60}Co room type gamma source (Shephard Model 81) was used for all exposures. Calibration is performed using MDH Ion chambers with accuracy traceable to NIST. Data is backed-up on magnetic media for easy archival and retrieval purpose.s.

Figure 1 below is a block diagram showing the basic setup of the radiation biasing scheme used for the work described in this paper. The In-Circuit Emulator and associated hardware used for this test cost approximately $5,000. A special 90° turn socket was designed and built so that the in-circuit emulator electronics could be shielded more effectively (See Fig. 1). With the ability to place the in-circuit emulator very near the radiation source, a capability is developed whereby considerable control over the microprocessor under test is available. By using a remote computer over RS-232 high-speed serial link, the microprocessor may be controlled to run any code necessary to test all modules and units of the device under test. Any register may be interrogated, traced and controlled. Virtually any sequence of code may be executed, including flight code.

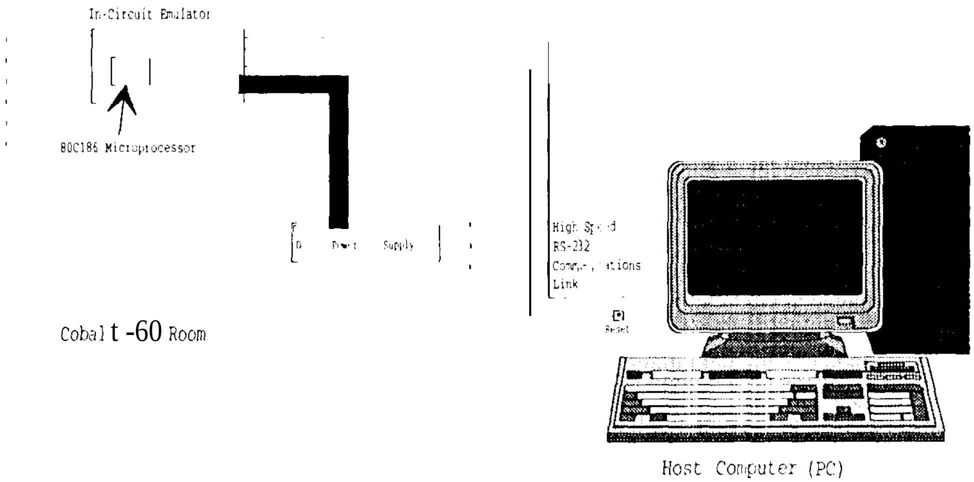

Figure 1. Diagram Showing Basic Setup of in-Circuit Emulator Test Approach.

EXPERIMENTAL RESULTS

Initial data were taken on the 80C186 for two manufacturer's devices: Intel and AMD. In-situ biasing consisted of running a sieve program, written in C, which locates prime numbers. All electrical parameters and functional measurements were run in-between radiation levels at a remote test system. Remote electrical characterization was performed using the Hewlett Packard 82000 digital test system while the emulator was used to check functionality. Two parameters of importance that were measured at each radiation dose are standby and operating supply current. These measurements were taken at the following frequencies: Static, 10MHz, 12 MHz and 16 MHz. Figure 2 below plots data for the Intel and AMD 80C186 16 bit microprocessor.

As can be seen in Figure 2 below, there is a large difference in performance between the Intel and AMD processors. The AMD device exhibits a more gradual degradation than does the Intel device. While the AMD microprocessor was still functional in the in-circuit tester at 100 krad(Si) it was drawing in excess of 200 mA supply current at 16 MHz. The AMD specification for dynamic supply current at 16 MHz is 80 mA and was exceeded at 30 krad(Si). The Intel microprocessor exceeded the manufacturer's specification of 160 mA at 10 krad(Si). Dynamic supply current (12.5 MHz) reached a maximum of well over 500 mA at 14 krad(Si) at which time functional failure was observed.

Post irradiation recovery was pa-formed for all devices. This consisted of dynamically biased room temperature anneals for 144 hours for Intel and 20 hours for AMD. Dynamic bias was achieved using the in-circuit emulator with the same program running as during the irradiation test. Both devices recovered favorably but not fully. Accelerated annealing data will be included in the full paper.

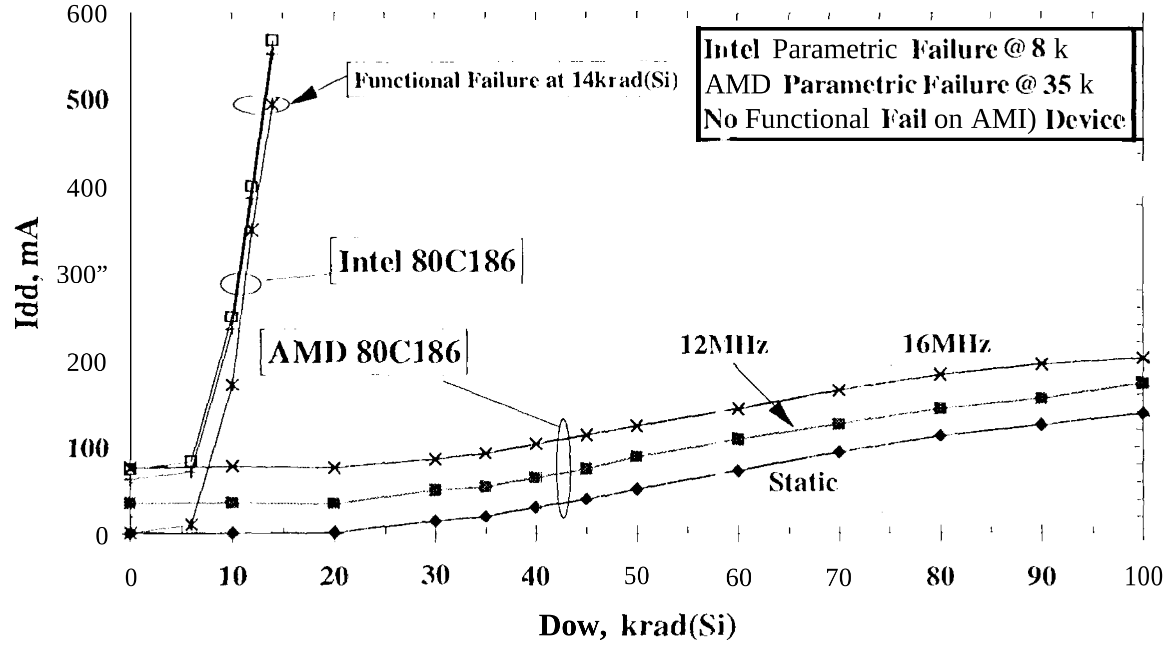

Figure 2. Plot of 80C186 Supply Current Measured at Several Frequencies Verses Dose for the AMD and Intel Microprocessors. Note The Large Difference in Radiation Response Between the Two Microprocessors.

The large difference in performance in the AM 1) and Intel microprocessors is probably due to gate and field oxide leakage mechanisms. The Intel device, with a rapid increase in supply current followed by functional failure would indicate a field oxide leakage mechanism. On the other hand, the AMD device exhibited a slower, more gradual increase in supply current with no functional failure, indicating a gate oxide leakage mechanism [13]. 'The full paper will explore these differences and show data that determine the effect of radiation bias on this family of microprocessors using an in-circuit emulator.

REFERENCES

[1] A. Holmes-Siedle and L. Adams, Handbook Of Radiation Effects, First Edition, (Oxford, Oxford University Press, p. 143, 1993).

[2] S. Yoshioka et.al, "A Radiation-Hardened 32 bit Microprocessor Based on the Commercial Process," IEEE Trans. Nucl. Sci., NS-41, 2481-2486, 1994.

[3] S. G. Mulford, "Total Dose Radiation Testing of the Intel 803861)X Microprocessor and 803871)X Math Coprocessor Using A personal Computer Motherboard For the Test 1 'ixture," 1} :EE NSREC Workshop Record, 26-29, 1994.

[4] A. K. Sharma, K. Sahu and J. Lander, "An Evaluation of the Radiation Tolerance of a 32-bit Microprocessor For Space Applications," IEEE NSREC Workshop Record, 30-36, 1994.

[5] A.H Johnston, "Annealing of Total Dose Damage in the Z80 Microprocessor," IEEE Trans. Nucl. Sci., NS-30, 4251.1983.

6] F.W Sexton et. al, "Radiation Testing of the CMOS 8085 Microprocessor Family," IEEE Trans. Nucl. Sci., NS 30, 4253, 1983.

[7] R. Koga et. al, "Techniques of Microprocessor Testing, and SEU Rate Predictions," IEEE Trans. Nucl. Sci., NS-32, 4219, 1985.

[8] K.J. Hass ct. al, "A Radiation Hardened 16/32-bit Microprocessor," IEEE Trans. Nucl. Sci., NS-36, 22 S2-2257, 1989.

[9] J.H. Elder, J. Osborn, W.A. Kolasinski, R. Koga, "A Method For Characterizing A Microprocessor's Vulnerability to SEU," Trans. Nucl. Sci., NS-35, 1678-1681, (1988).

[10] B.],. Gingerich, J.M. Hermsen, J.C. Lee, "Total Dose Rate Radiation Characterization of FYI-CMOS Radiation Hardned Memory and Microprocessor Devices," Trans. Nucl. Sci., NS-31, 1332-1336, (1984).

[11] K. Marks and P. Measel, "Total Dose Test Results for the 8086 Microprocessor," Trans. Nucl. Sci., NS-29, 1662-1664, (1 982).

[12] F.W. Sexton ct. al, "Radiation Testing of the 8085 Microprocessor Family," Trans. Nucl. Sci., NS-30, 4235-4239, (1983).

[13] "T.P. Ma and P.V. Dressendorfer, Ionizing Radiation Effects In MOS Devices And Circuits, First Edition, (New York, Wiley, p. 179, 1989.