Total-Dose and SEU Results for the AD8001, a High-Performance Commercial Op-amp Fabricated in a Dielectrically-Isolated, Complementary-Bipolar Process *

Michael DeLaus
Analog Devices Semiconductor
804 Woburn Street
Wilmington, MA 01887

William Combs
Naval Surface Warfare Center
Code 6054, Building 2088
Crane, IN 47522-3806

ABSTRACT

Radiation test results are presented for the AD8001. This part is a state-of-the-art commercial op-amp fabricated on an advanced dielectrically-isolated process featuring lateral trench isolation and a bonded wafer substrate. Both Cobalt-60 and SEU results are discussed. No total-dose failures were seen for exposures of >1Mrad(Si). No single-event induced latchup was observed up to the maximum LET (82.0 Mev-cm^2/mg) used in this study.

I. INTRODUCTION

As system designers and program managers come under increased pressure to reduce system costs, they continue to look to commercial off-the-shelf parts to meet their cost, performance, and hardness requirements. Because of the sometimes divergent needs of the commercial and military/radiation-hardened markets, many commercial parts and processes do not lend themselves to such applications.

The XFCB process from Analog Devices has a number of unique characteristics that allow it to provide the high level of performance required by the commercial sector and the radiation hardness required for military and space applications. In this paper, ionizing radiation and Single Event Upset (SEU) test results are presented for XFCB NPN and PNP bipolar transistors and for the AD8001, a high-performance op-amp fabricated on the XFCB process.

II. TECHNOLOGY DESCRIPTION

A. Process Features

XFCB is a high-speed, complementary-bipolar, dielectrically-isolated process. Details of this process have been previously discussed[1]. The process features fast NPN and PNP transistors which are isolated laterally by oxide/polysilicon filled trenches and built on a bonded-wafer substrate. The device cross-sections appear in Figure 1. A summary of the device parameters is presented in Table 1.

A number of features of XFCB provide both excellent performance and good radiation tolerance. The trench/SOI isolation scheme was chosen because it minimizes parasitic capacitances which limit circuit performance, and it allows for high packing density. The benefits of trench/SOI dielectric isolation (DI) in radiation environments are well documented[2]. Latchup is eliminated, photocurrent collection is greatly reduced, and circuit upset levels are increased. Trench isolation also prevents device-to-device leakage caused by field inversion. XFCB contains laser trimmable thin-film resistors which are frequently used by analog designs for their precision. These Chrome-Silicon resistors are very tolerant to ionizing radiation and displacement damage.

B. Circuit Description

The AD8001 is a high-performance, low-power, current-feedback op-amp designed for video, imaging, and battery/portable applications. The AD8001 features a 800-MHz unity gain bandwidth and a 1200 Volt/µsec slew rate. For it's power consumption (50 mW), it is the fastest amplifier available. This makes the part ideal for satellite applications. The AD8001 is clearly a state-of-the art amplifier.

III. RADIATION TEST RESULTS

The radiation evaluation of the AD8001 focused on the two primary environments of concern for space system designers; ionizing radiation, and SEU. Degradation in circuit performance and perhaps circuit failure due to ionizing radiation

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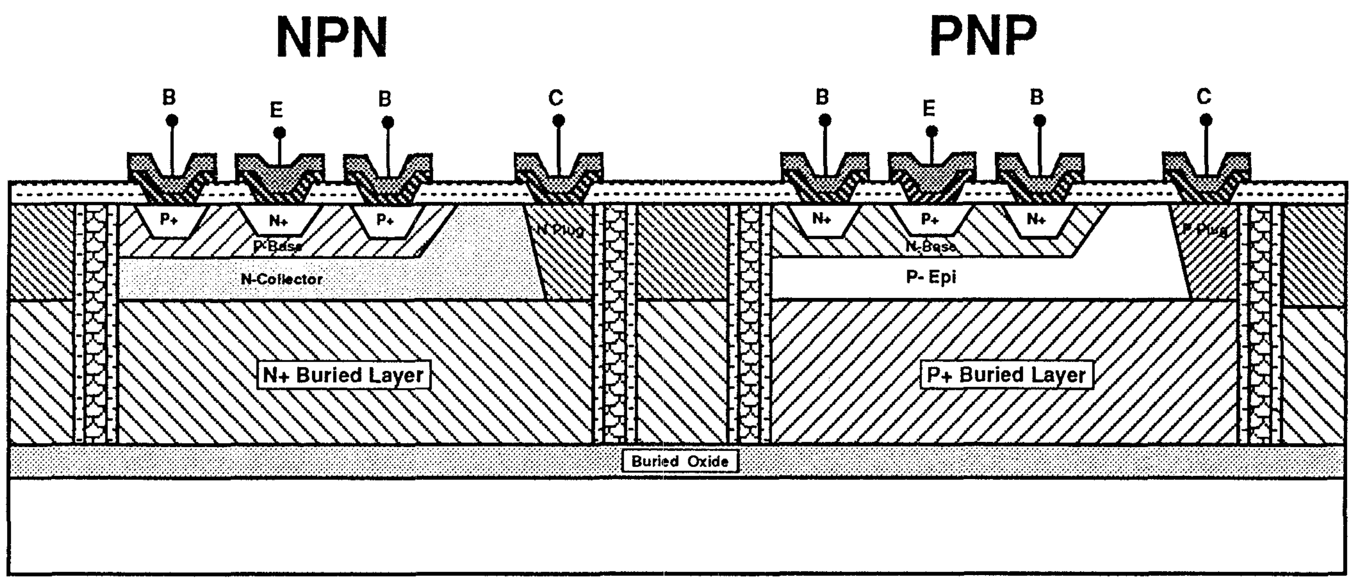

FIGURE 1. Device cross-sections of XFCB NPN and PNP transistors.

Parameter	NPN	PNP
β	95	70
V_A	95 V	20 V
BV_{CEO}	>12 V	>14 V
BV_{CES}	>25 V	>14 V
BV_{CBO}	>25 V	>25 V
$F_T@V_{CE}=2V$	4.5 GHz	2.5 GHz
R_B	40 Ω	85 Ω
I_{KF}	9.0 mA	2.5 mA

TABLE 1. XFCB Device Parameters.

results from total-dose accumulated from charged particles trapped in the earth's magnetic belts. SEU events are the result of interactions with cosmic-ray heavy ions and protons. The data presented in this paper represent the initial results of the total-dose and SEU evaluations of the AD8001.

A. Total-Dose Results

Total-dose testing was performed on XFCB NPN and PNP transistors and AD8001 circuits. The transistors are representative of the devices used in the circuit. To provide results that would be useful to space system designers, the total-dose evaluation was performed at 2 different dose rates. A standard laboratory dose-rate of 150 rad(Si)/sec was used for the initial evaluation. This dose-rate is within the range required by MIL-STD-883D, test method 1019.4 for parts qualification. To investigate the effects of dose-rate on the device response, parts were also irradiated at a dose-rate of 1.5 rad(Si)/sec. The effect of dose-rate is important, as the actual dose-rate in the space environment is many orders of magnitude below the dose-rates typically used for laboratory testing.

All total-dose exposures were made with a Shepherd Model 81-22 ^{60}Co cell. A thin Al-Pb box was used to filter low energy photons. Transistor measurements were made in-situ, while the circuits were removed from the cell for testing.

1. Bipolar Transistors

Total-dose testing of XFCB NPN and PNP transistors did not reveal any significant sensitivities to ionizing radiation. As expected, the transistor gain did decrease due to increases in radiation induced recombination currents, but there was no increase in collector-to-emitter leakage. The test results for the NPN and PNP devices are shown in Figures 2 and 3 respectively. All transistor terminals were grounded during the exposures, which were made at 150 rad(Si)/sec. The gain measurements were made with a collector-base voltage of 0 volts.

The effect of dose-rate on the total-dose response of advanced bipolar transistors has been previously documented[3]. In general, the gain degradation is worse at lower dose rates. A previous study[4] has shown that this is the case for XFCB transistors.

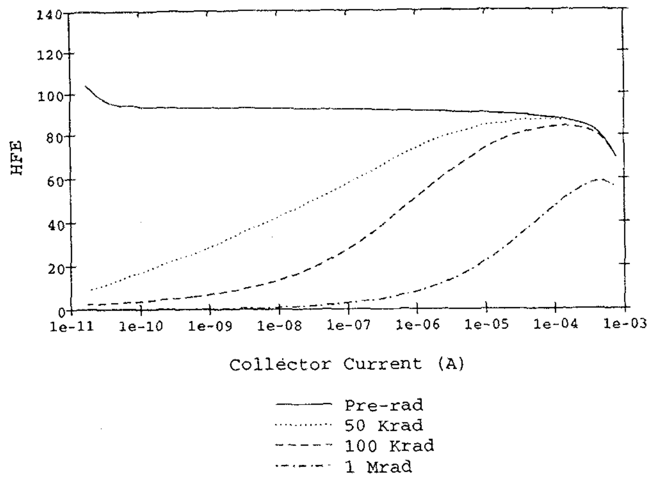

Figure 2. Total-dose response of XFCB NPN transistor.

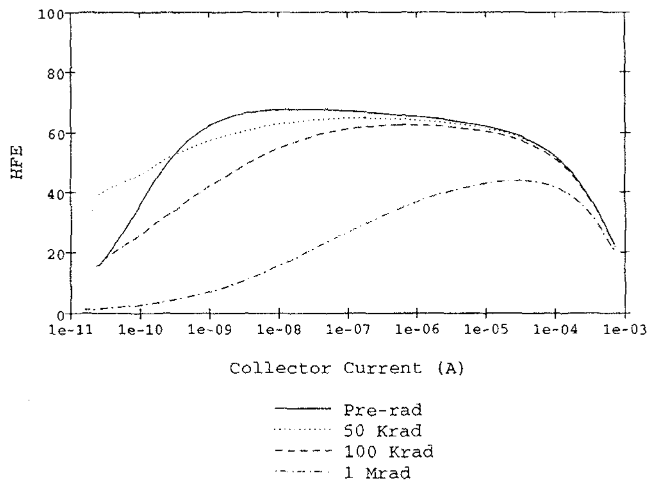

Figure 3. Total-dose response of XFCB PNP transistor.

2. Circuit Results

AD8001 circuits were exposed at high and low dose rates. During the exposures, the parts were biased with +/- 5V power supplies and the inputs were grounded. The parts were in a 2X gain, non-inverting configuration. Prior to testing, the parts were checked to insure that they were not oscillating.

The pre- and post-radiation electrical testing was performed on a bench top linear tester. The parts were removed from the cell for testing. The test program measured all of the data sheet DC parameters, including supply currents, input bias currents, input offset voltage, CMRR, PSRR, output voltage swing, and short-circuit current. All of the parts continued to function after the exposures.

The 150 rad(Si)/sec pre- and post-radiation electrical data are presented in Figures 4-12. These graphs contain the results for 2 individual parts. In some cases the data overlap, and appear as a single curve. The only circuit parameters that exhibited significant shifts (> 15%) were input bias currents and offset voltage.

The low dose-rate results were similar to the high dose-rate results in that only the input bias currents and input offset voltage exhibited significant change. Only the data for these tests are presented. To compare the high and low dose-rate responses, Figures 13-15 present the relative changes in the V_{IO}, $+I_{bias}$, and $-I_{bias}$ parameters.

B. SEU Testing

SEU testing was conducted at the Tandem Van de Graaff facility at Brookhaven National Laboratory. During the testing, op-amps from a number of commercial manufacturers were evaluated. The devices were exposed to 283 MeV Bromine and 345 MeV Gold ions. The respective LETs were 37.2 and 82.0 MeV-cm^2/mg. During the exposures, the parts were biased with +/-5V power supplies and the inputs were grounded.

The devices were exposed to a fluence of 2E6 #/cm^2. No latchup was observed. A peak detector circuit monitored the output of the op-amp. The number of peaks above a pre-selected threshold was recorded. The preliminary results indicate that the AD8001 had significantly fewer "upsets" than similar op-amps fabricated on junction-isolated processes.

IV. DISCUSSION

The total-dose results for the AD8001 are very encouraging. No functional failures were observed. Parametric failures did occur, but only at exposures >1Mrad(Si) and only at a dose-rate of 150 rad(Si)/sec. No parametric failures occurred during the low dose-rate testing.

Based on the circuit design, the increase in input bias current can be directly attributed to the decrease in transistor gain. The decrease in transistor gain is caused by an increase in the transistor base current due to an increase in surface recombination above the emitter-base junction. The input bias currents are directly proportional to the transistor base current. Base currents of both NPN and PNP devices contribute to the input bias currents. This may account for the turn around in the bias currents during the high dose-rate exposures. If the NPN and PNP gains degrade at varying rates, the bias currents could shift initially in one direction and then appear to head back in the other direction. More analysis is required to confirm this theory.

V. CONCLUSIONS

The AD8001 is well suited for military and space applications that require high performance, excellent speed/power characteristics, and good radiation tolerance. Similar results are expected for other circuits fabricated on XFCB.

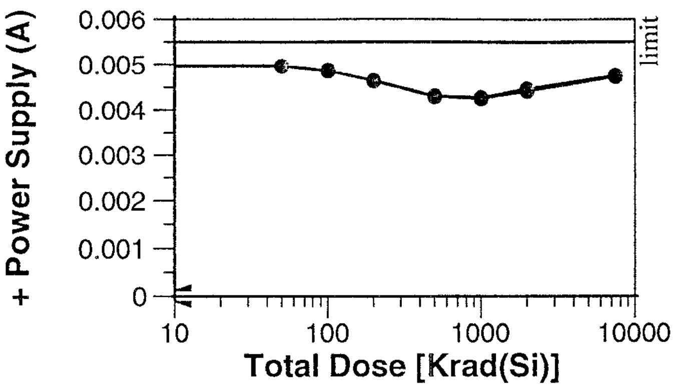

Figure 4. AD8001 +supply current.

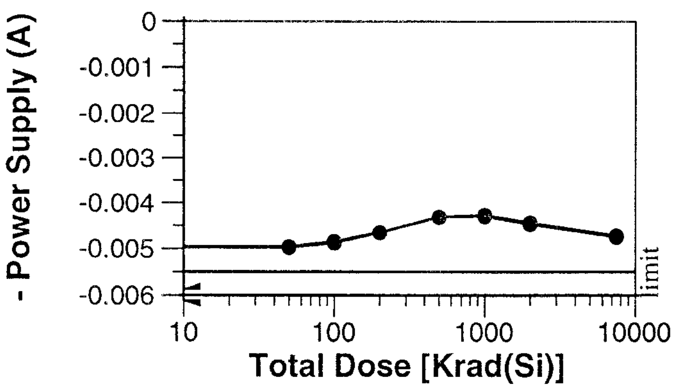

Figure 5. AD8001 -supply current.

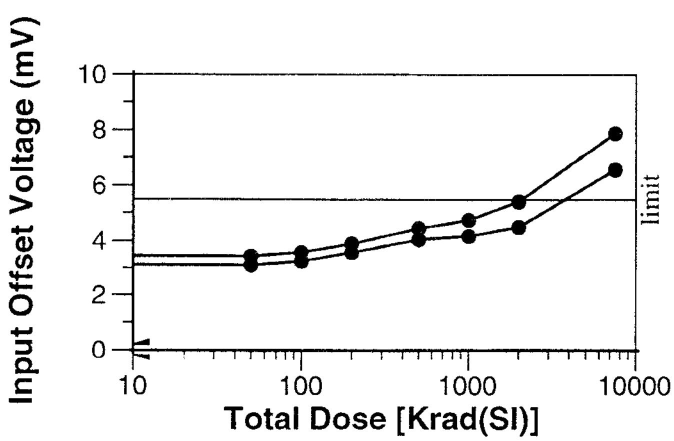

Figure 6. AD8001 input offset voltage.

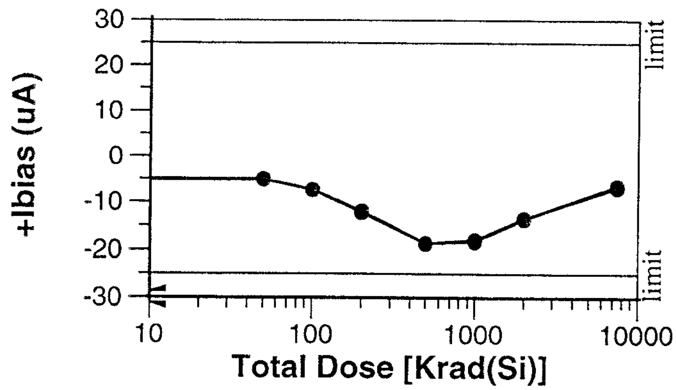

Figure 7. AD8001 +input bias current.

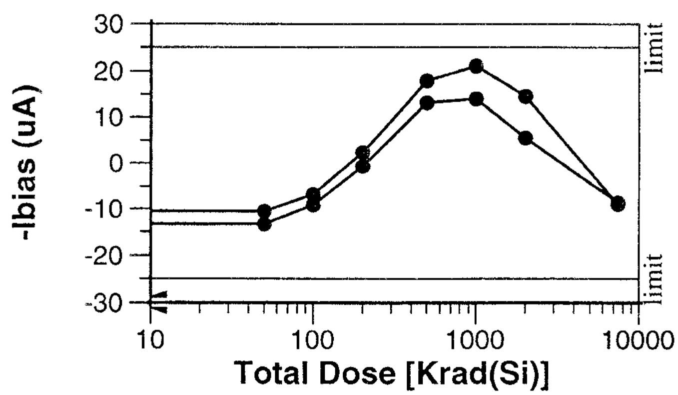

Figure 8. AD8001 -input bias current.

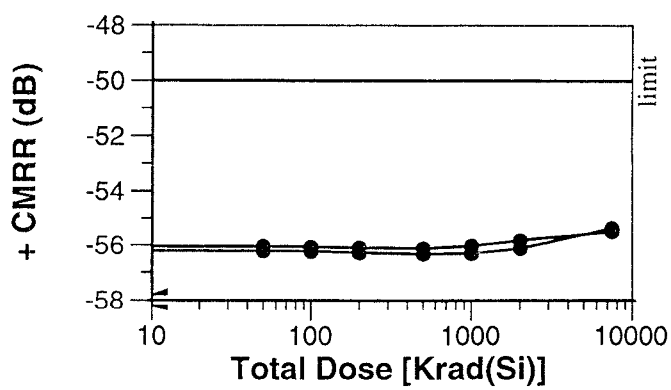

Figure 9. AD8001 +common mode rejection ratio.

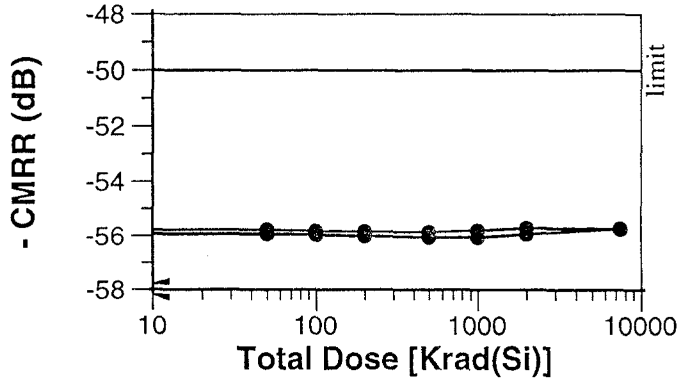

Figure 10. AD8001 -common mode rejection ratio.

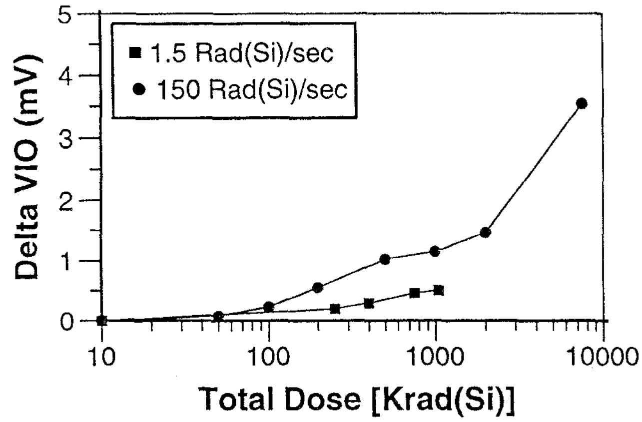

Figure 13. Change in AD8001 input offset voltage for high and low dose-rate exposures.

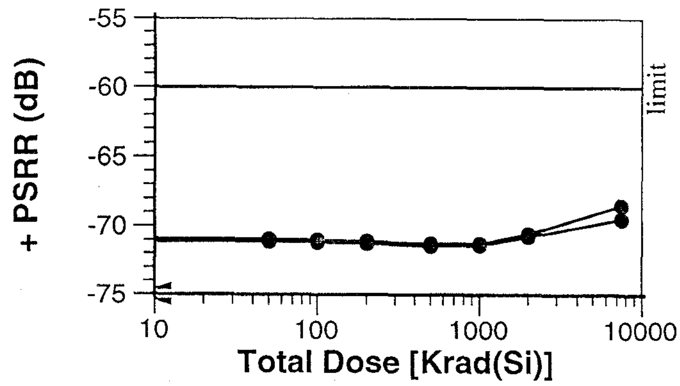

Figure 11. AD8001 +power supply rejection ratio.

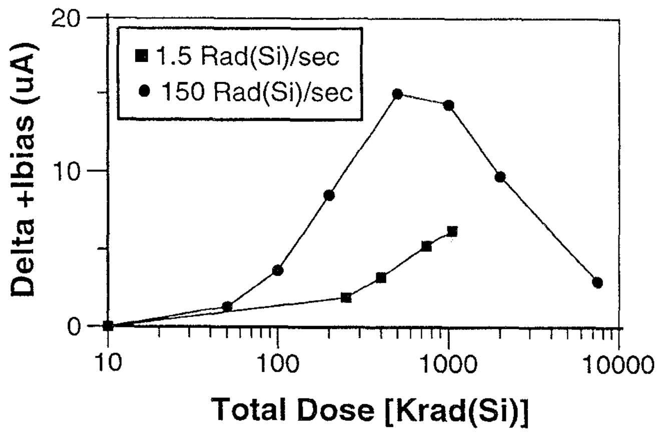

Figure 14. Change in AD8001 +input bias current for high and low dose-rate exposures.

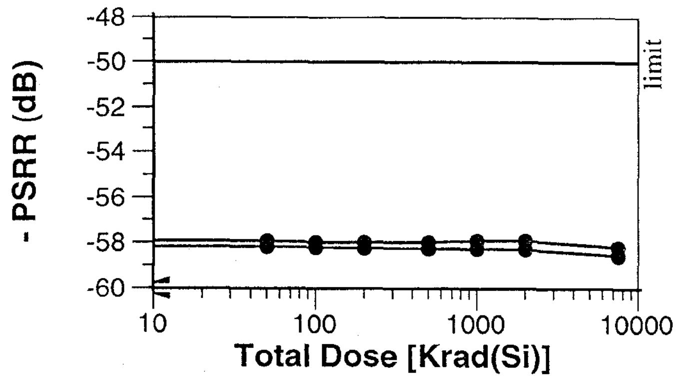

Figure 12. AD8001 -power supply rejection ratio.

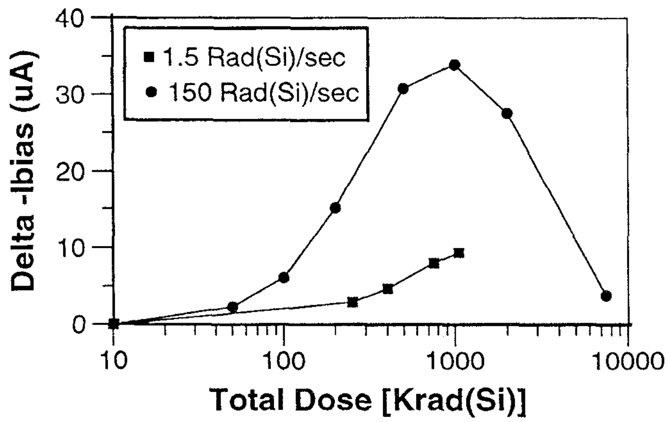

Figure 15. Change in AD8001 -input bias current for high and low dose-rate exposures.

ACKNOWLEDGMENTS

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