Total Dose Dependency and ELDRS Effects on Bipolar Linear Devices*

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I. INTRODUCTION

The use of bipolar linear devices is prevalent in most satellite and some space applications. However, degradation as a result of low dose irradiations known as ELDRS (effects of enhanced low dose rate sensitivity) is a major concern when selecting flight hardware. The reason for this is because space programs receive low dose radiation over numerous months and years. Many studies and reports have been conducted on this phenomenon [1]-[2] as well as their responsible physical mechanisms [3].

The testing of four different bipolar linear circuits will be presented in this summary. They include a dual voltage comparator, temperature transducer and two voltage reference devices. Testing done include high dose rate and low dose rate testing for biased and unbiased conditions. In addition, medium dose rate testing at 100 C was conducted as an evaluation of an accelerated ELDRS test methodology. The purpose of these tests was to characterize these parts for total dose environments and to assess suitability for use in space systems. Additionally, these tests assist in further understanding the effects of ELDRS under a wider range of conditions. A reminder must be made that the dose rates used here does not guarantee that device performance at low dose rates has been bounded. Additional testing should be done to study possible degradation at lower dose levels.

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II. EXPERIMENTAL DETAILS

A. Device Descriptions

A list of tested devices is shown on Table I. Testing for additional devices are currently underway and expect to be added.

B. Total Dose Facilities

Total dose irradiations for all parts were performed at the Co-60 range source at the Jet Propulsion Laboratory, Pasadena, CA. High dose rate exposure was approximately 50rad(SiO^2)/s, medium dose rate was approximately 0.20rad/SiO^2)/s, and low dose rate exposure ranged between 0.01 to 0.06rad/SiO^2)/s. All irradiations were compliant to Mil-STD-883, Method 1019 and NIST traceable. Lead and aluminum shields were used to absorb low energy gamma rays.

C. Electrical Tests

All parts were electrically tested with an LTS2020 mixed signal automated test system located adjacent to the Co-60 range source. Pre and post irradiation tests were performed according to DC test parameters listed in the vendor or military specifications.

D. Procedure

Each part was tested at low dose rate for biased and unbiased conditions as well as biased conditions for high dose rate. The one exception to this was the LM185-1.2 in which high dose rate tests was done only for unbiased conditions and also included an accelerated ELDRS test at medium dose rate. Table II provides a comprehensive outline of the test conditions for the parts tested. Three to five parts were tested for each of the different conditions. At the beginning

TABLE I
IDENTIFICATION OF TESTED PART TYPES

Generic	Part Number	Date Code	Die Manufacturer	Description	Procured as
LM193	M38510/11202BPA	9950G	National Semiconductor	Dual Comparator	Military grade "B" hermetic
LT1019-2.5	LT1019CN8-2.5	0040	Linear Technology	2.5V Precision Reference	Military grade hermetic –
LM185-1.2	LM185WG-1.2/883	H9C0039F	National Semiconductor	1.2 Voltage Reference	Military grade hermetic -
LM134	LM134-H	9420	Linear Technology	Temperature Transducer	Commercial TO-46

of each experiment, parts were measured prior to irradiation and measured at step-levels thereafter. The time between irradiation steps for electrical tests occurred within one to two hours of each other. Also, low and high dose rate tests were conducted within a period of a month or less to ensure minimal errors due to equipment calibration changes.

TABLE II
IRRADIATION BIAS CONDITIONS

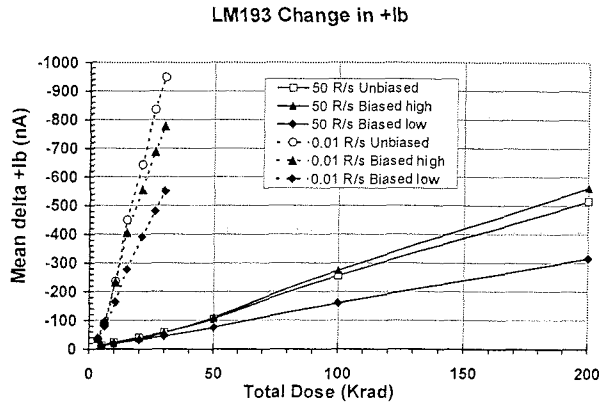
	LM193	LT1019-2.5	LM185-1.2	LM134
LDR	3 B – .01r/s 3 U – .01r/s	3 U – .01r/s 5 B – .01r/s	3 U – .01r/s 3 B – .01r/s	3 B – .02r/s 3 U – .02r/s
HDR	3 B – 50r/s 3 U – 50r/s	5 B – 50r/s	3 U – 50r/s 2 U – .25r/s	2 B – 50r/s
Bias	15V Input A – High Input B - Low	2.5Vout, 1kohm	1.25mA through 10Kohm	300 uA through 230 ohm
Results	LDR worse than HDR. Unbiased LDR worse than biased LDR. Unbiased HDR better than biased HDR.	LDR worse than HDR. Biased LDR worse than unbiased LDR.	LDR worse than HDR. Unbiased LDR worse than biased LDR.	LDR worse than HDR. Behavior of biased LDR similar to unbiased LDR.

* # Of parts – Biased/Unbiased –Dose Rate
* Unbiased parts had all leads shorted.

IV. TEST RESULTS AT HIGH AND LOW DOSE RATE

A. LM193 Dual Comparator

The LM193 is the counterpart of the previously tested LM139 quad comparator [4]. For all test groups, the input bias current (Ib) degraded the most with respect to the specification, followed by the input offset current (Ios), and then input offset voltage (Vos). The change in Ib was far more rapid for the low dose rate groups than for the high rate groups and exceeded the specification between 3.6 and 6 krad test levels. Bias condition did not have a significant effect on this parameter as indicated in the figure below. Although Vos remained within specification to the highest levels tested, this parameter exhibited both bias and dose rate dependence. It is interesting to note for Vos that while the unbiased case was worse at low dose rate, the opposite was true for the high rate case. Furthermore, the parameter change was in opposite directions for the input high and input low



conditions.

Fig. 1

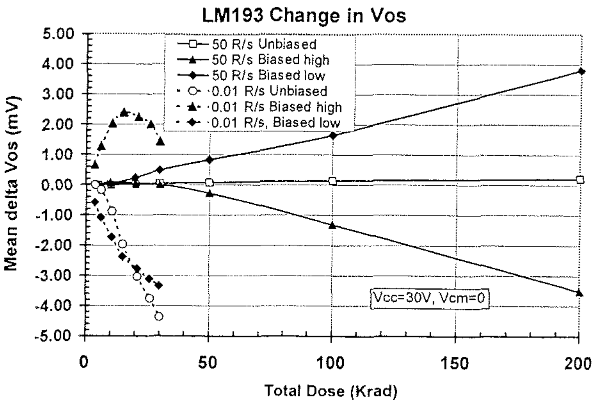


Fig. 2

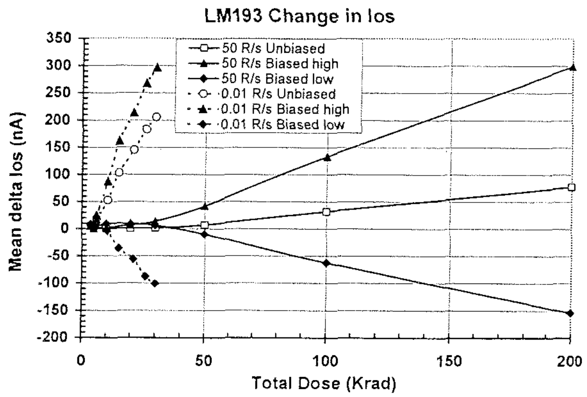


Fig. 3

B. LT1019-2.5 Voltage Reference

This device exhibited Enhanced Low Dose Rate Sensitivity (ELDRS) with output voltage for the biased low dose rate case degrading approximately four times faster than the biased high dose rate case. A slight bias dependency is indicated with the biased case being slightly worst. The low dose rate groups performed within the manufacturer's pre-radiation specification to greater than 10 krad while the biased group remained within specification to greater than 30 krad. Output voltage and line regulation failures occurred at the 17 krad test level for the low dose rate case. In contrast, these failures did not occur until 50 krad for the high dose rate case. The remaining test parameters were within specification at all test levels. Parts in the high dose rate group recovered somewhat after a one-hour biased anneal. Bias and dose rate comparison plots for Vrline and Vout are provided below.

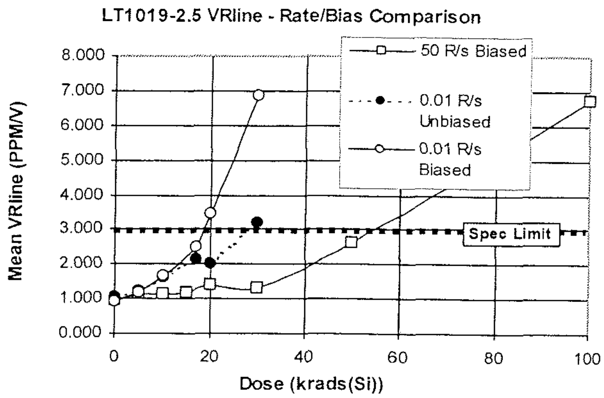


Fig.4

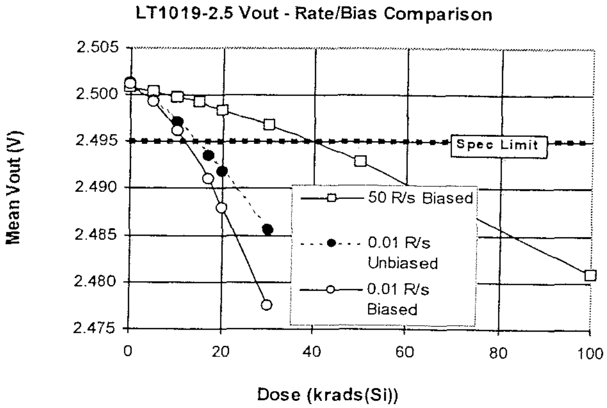


Fig. 5

C. LM185-1.2 Voltage Reference

For all test groups, reference voltage was the primary parameter of interest. Though degradation was also found for breakdown voltage change with current, these failures were due to large changes in the breakdown voltage alone. The device exhibited Enhanced Low Dose Rate Sensitivity (ELDRS) with the reference voltage for the low and medium dose rate cases degrading far more than for the unbiased high dose rate case. For the low dose rate case, the unbiased condition degraded faster than the biased case with the reference voltage going out of specification between 5 and 10 krad. The initial tendency for reference voltage for the low rate groups was to decrease then to increase after 20krad. The medium rate group showed the same tendency but at an earlier point, between 5 and 17 krad and the degradation for this group was significantly more than for the low rate group in general. In contrast, the high dose rate group had very little degradation out to the highest level tested, 100 krad.