Total Ionizing Dose Test of Silicon Switching Transistors JANTXV2N2222AUB

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1. Introduction

Semicoa's silicon switching transistors, JANTXV2N2222AUB[1] was tested for total ionizing dose (TID) response beginning on November 4, 2019. This test served as the radiation lot acceptance test (RLAT) for the lot date code (LDC) tested. Low dose rate (LDR) irradiations were performed in this test so that the device susceptibility to enhanced low dose rate sensitivity (ELDRS) could be determined.

2. Devices Tested

2.1. 2N2222 Background

The 2N2222 is a radiation hardness assured (RHA) three port, high speed switching NPN bipolar junction transistor (BJT) screened to a JANTXV performance level. It is used in high-reliability applications and is suitable for space flight projects.

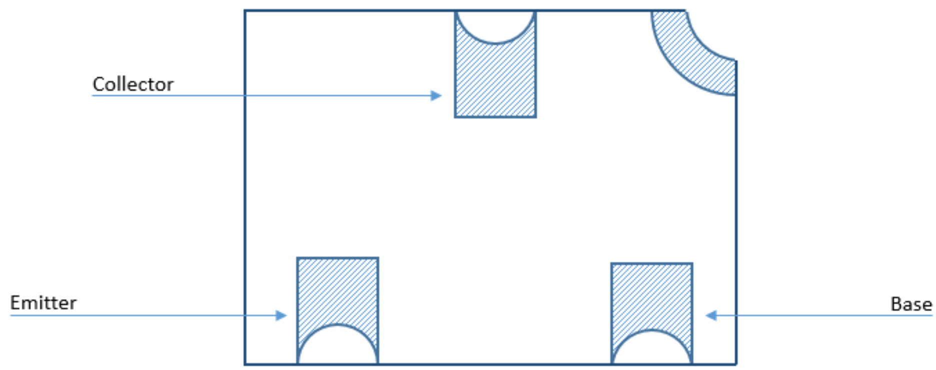

Figure 1: Pin out for 2N2907/2N222.

2.2. Device under Test (DUT) Information

Five 2N2222s were irradiated at an average dose rate of 10mrad (Si)/s using a 1 MeV gamma source. One device was used as a control. The five samples of the 2N2222s were irradiated unbiased with all pins grounded. The DUTs were packaged in a three port UB package which is a ceramic with a metal lid.

[1] Abbreviated as 2N2222

Table 1: Part Information

Part Number:	JANTXV2N2222AUB
Manufacturer:	Semicoa
Date Code:	1541*T
Quantity Tested:	5, Plus 1 Control
Part Function:	Switch
Part Technology	BJT
Package Style	UB

3. Test Setup

3.1. Testing of Semicoa's 2N2222

The unbiased samples had all leads grounded.

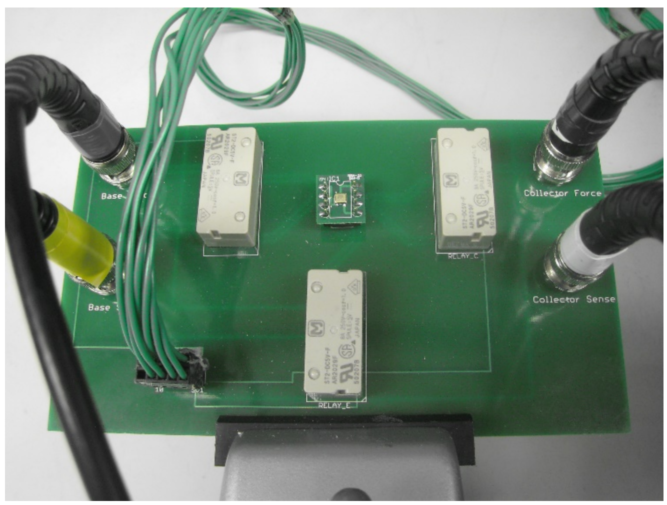

Figure 2: Test Board

In addition, the setup used a Keithley pulse meter and a Keithley source meter connected to a test board containing the DUTs. This was all then connected to a computer with LabVIEW running APAPP 2017.1[2].

[2] Radiation Effects Analysis Group Software

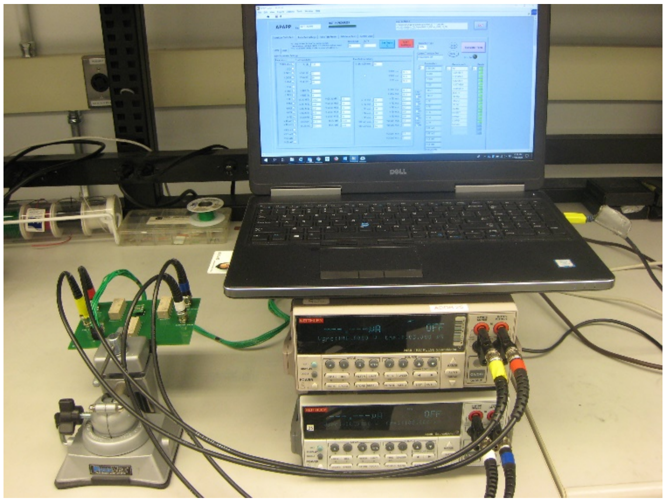

Figure 3: Parameter analyzer setup.

4. Test Description

4.1. Irradiation Conditions and Step Stress

A 1 MeV gamma source, compliant with MIL-STD-883 Method 1019, was used to irradiate the five devices at a LDR. The maximum dose rate was 10 mrad (Si)/s. Prior to the first radiation dose, all six BJTs were electrically tested to confirm that they were within the specifications given on each respective data sheet. After each exposure level, given in Table 2, the samples were tested again. Electrical tests performed are given in Table 3.

Table 2: Device Grouping and Step-Stress Instructions

Group	Type	Quantity	Bias	Dose Rate	Exposure Level Steps (krad(Si))
1	2N2222	5	Unbiased	LDR 10 mrad(Si)/s	0, 1, 2, 5, 10, 15, 20, 30

Table 3: List of Electrical Tests Performed

Test	Symbol	Conditions T_A = +25°C 2N2222	Specifications (2N2222) Min	Max
Collector-Emitter Voltage	V_{CEO}		50 V	
Collector Current	I_C			800 mA
Collector-Base Cutoff Current	I_{CBO}	75 V		10 µA
		60 V		10 ηA
Collector-Emitter Cutoff Current	I_{CES}	50 V		50 ηA
Emitter-Base Cutoff Current	I_{EBO}	6.0 V		10 µA
		4.0 V		10 ηA
Forward-Current Transfer Ratio	h_{FE1}	I_C = 0.1 mA, V_{CE} = 10 V	50	
	h_{FE2}	I_C = 1.0 mA, V_{CE} = 10 V	75	325
	h_{FE3}	I_C = 10 mA, V_{CE} = 10 V	100	
	h_{FE4}	I_C = 150 mA, V_{CE} = 10 V	100	300
	h_{FE5}	I_C = 500 mA, V_{CE} = 10 V	30	
Collector-Emitter Saturation Voltage	$V_{CE(sat1)}$	I_C = 150 mA, I_B = 15 mA		0.3 V
	$V_{CE(sat2)}$	I_C = 500 mA, I_B = 50 mA		1.0 V
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 150 mA, I_B = 15 mA	0.6 V	1.2 V
		I_C = 500 mA, I_B = 50 mA	0.6 V	2.0 V

5. Results

Five forward-current transfer ratios were examined for each type of BJT, as well as two collector-emitter saturation voltages. Average values for the unbiased cases have been plotted and contain error bars calculated from one standard deviation from the mean. The upper and lower bounds of the 99/90 K_{TL} one-side tolerance levels are also plotted. The K_{TL} value for five samples with a worst case of 99% and 90% confidence was 4.666.

The results of six samples (5 irradiated samples and one control) are shown below.

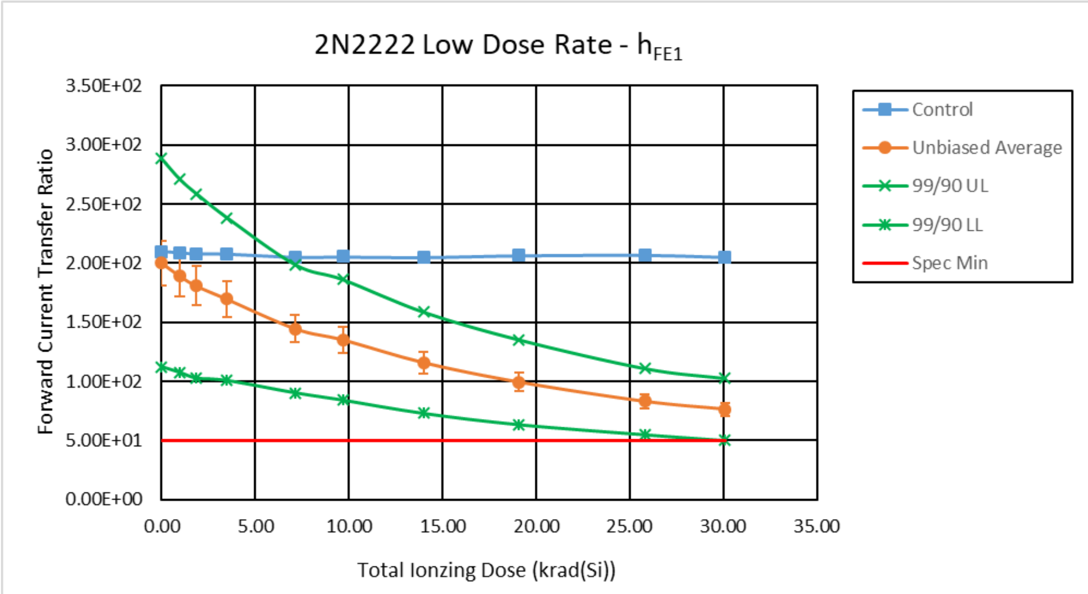

Figure 4: Forward-current transfer ratio 1.

The forward-current transfer ratio 1 degraded as the dose increased. After 30.1 krad(Si) the forward-current transfer ratio 1 stayed above the specification minimum.

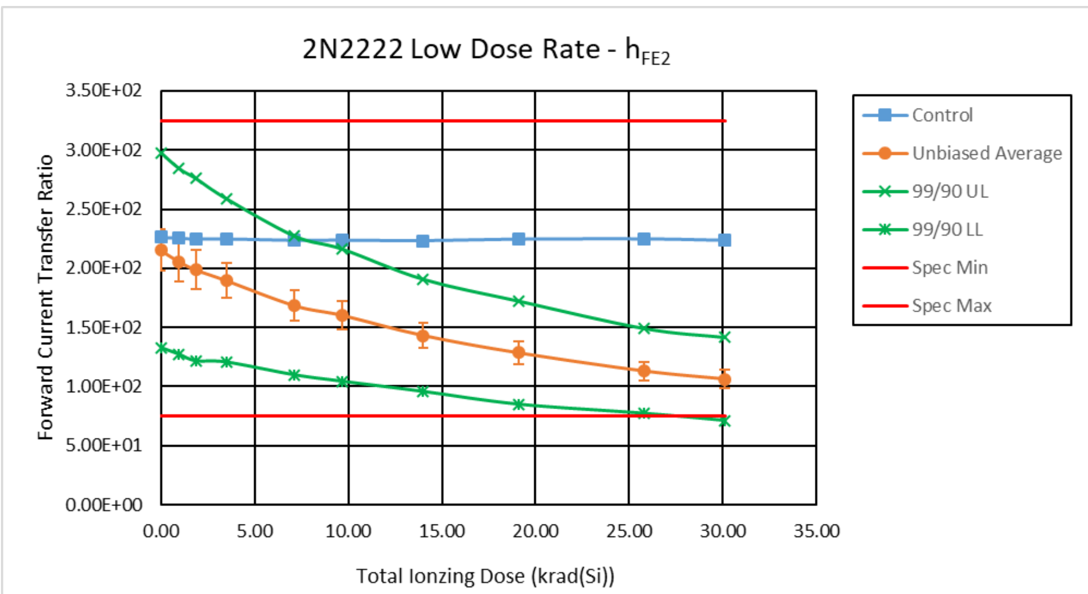

Figure 5: Forward-current transfer ratio 2.

The forward-current transfer ratio 2 degraded as the dose increased. At a dose of 25.8 krad(Si) the forward-current transfer ratio 2 was still above the specification minimum. After 30.1 krad(Si) the forward-current transfer ratio 2 fell below the specification minimum.

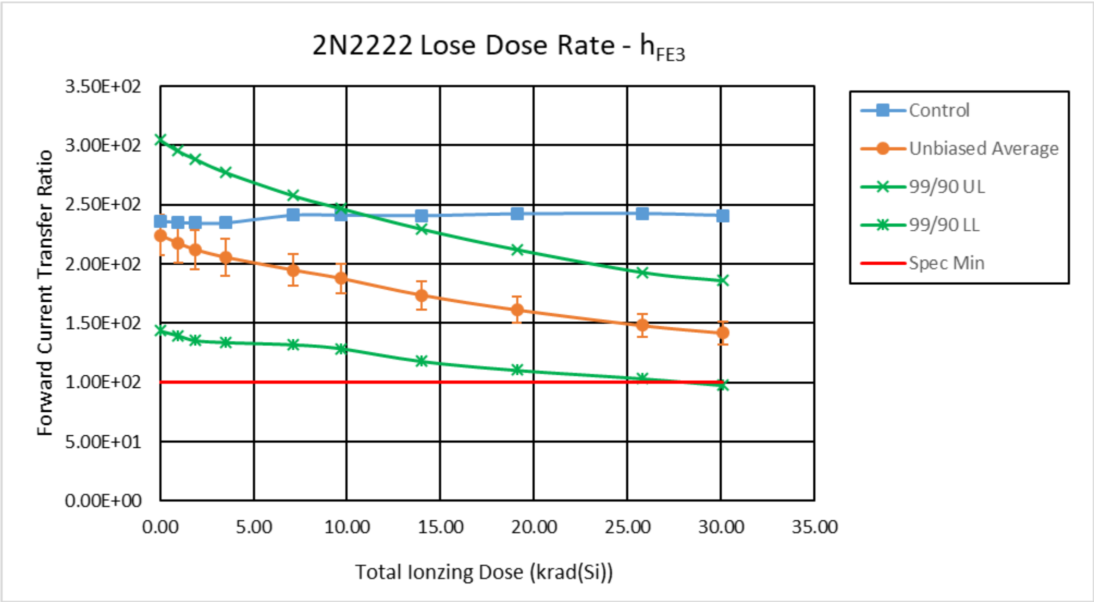

Figure 6: Forward-current transfer ratio 3.

The forward-current transfer ratio 3 degraded as the dose increased. At a dose of 25.8 krad(Si) the forward-current transfer ratio 3 was still above the specification minimum. After 30.1 krad(Si) the forward-current transfer ratio 3 fell below the specification minimum.

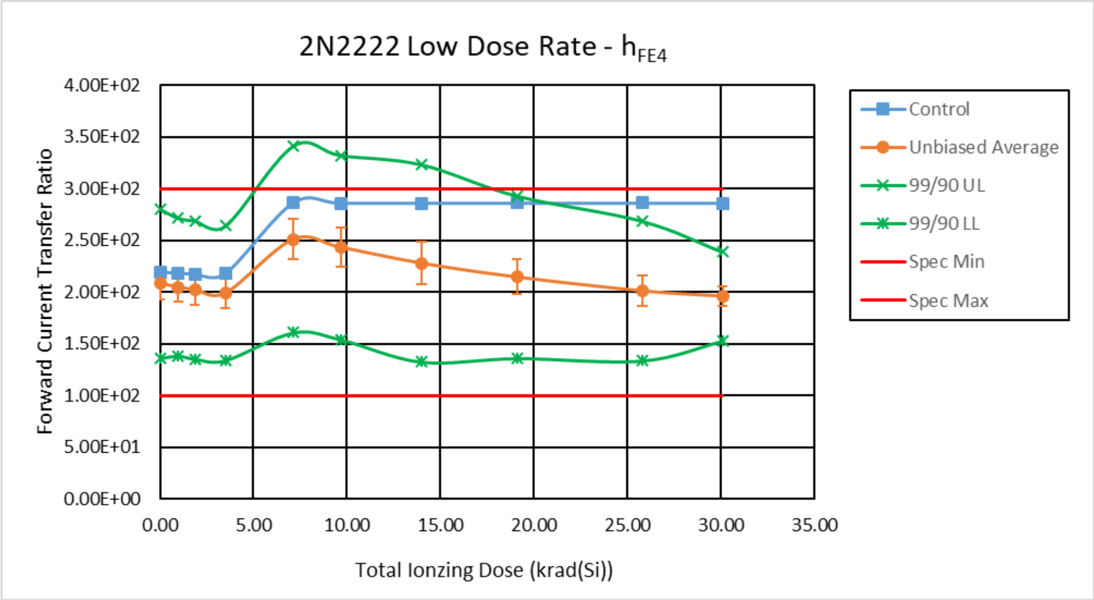

Figure 7: Forward-current transfer ratio 4.

The forward-current transfer ratio 4 degraded as the dose increased, except for the increase between 3.5 krad(Si) and 7.13 krad(Si). From 5 krad(Si) to 19.09 krad(Si) the upper limit of 99/90 tolerance level was greater than the specification maximum. During the testing of the forward-current transfer ratio 4, the current conditions changed. The first three data points were tested under a pulse current condition, while remaining data points were collected at a steady state condition. In addition, the cables connecting the test board to the Keithley source meter were changed. The first three data points used longer cables than the other points.

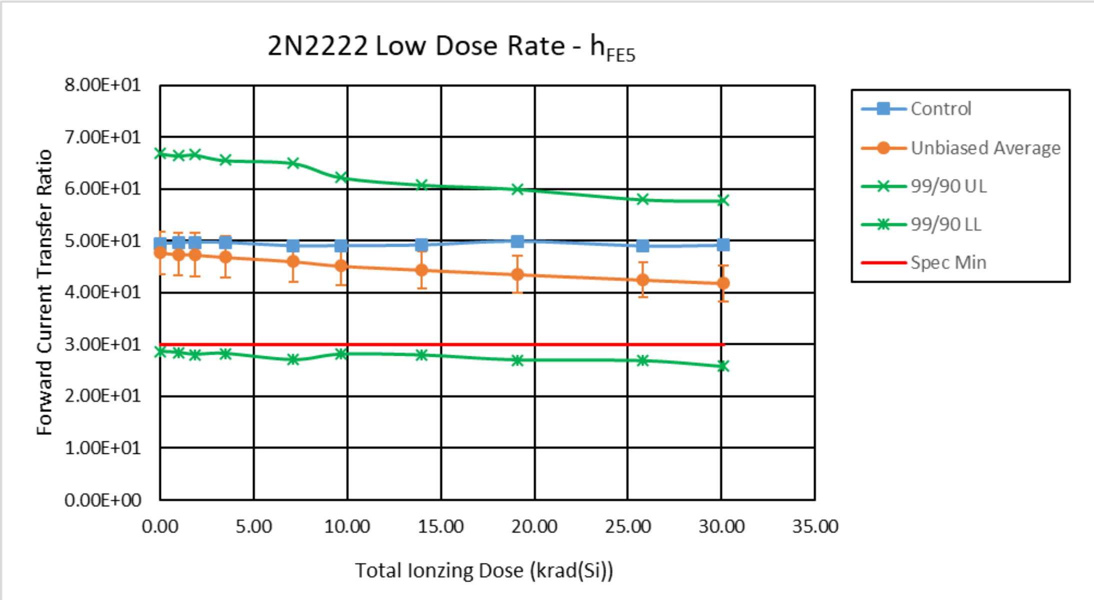

Figure 8: Forward-current transfer ratio 5.

The forward-current transfer ratio 5 degraded as the dose increased. The lower limit of the 99/90 tolerance level is less than the minimum specification for the forward–current transfer ratio 5 (table 3) for every dose value.

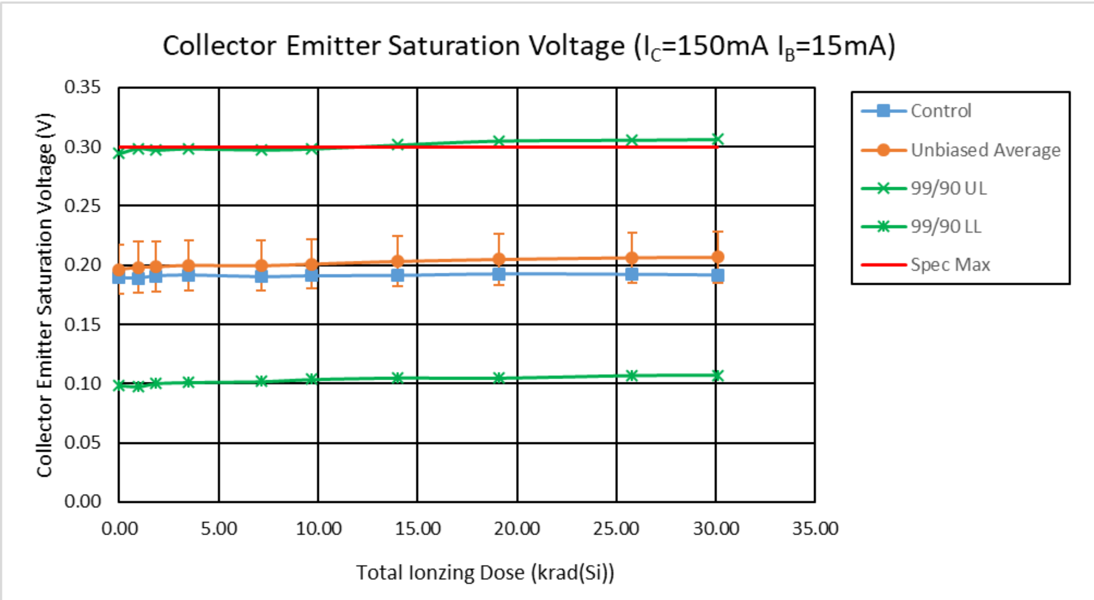

Figure 9: Collector-emitter saturation voltages 1.

As seen in Figure 9, the collector-emitter saturation voltage increased slightly thought out the irradiation process. The upper limit of the 99/90 tolerance level was below the collector emitter saturation voltage maximum specification until a dose of 9.68 krad(Si). After 14 krad(Si) the 99/90 tolerance level was above the maximum specification.

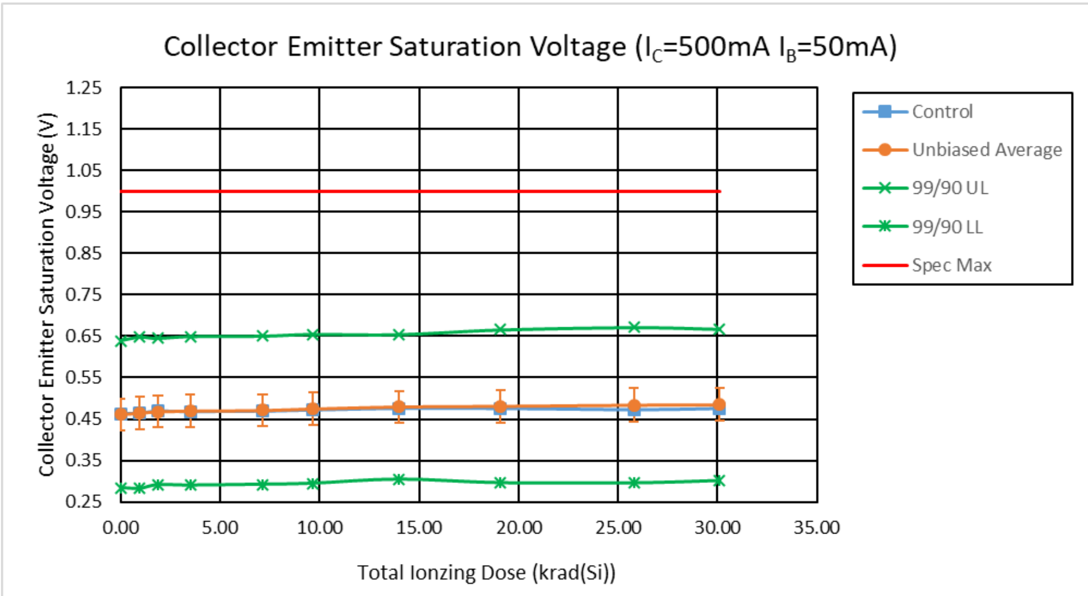

Figure 10: Collector-emitter saturation voltages 2.

As seen in Figure 10, the collector-emitter saturation voltage stayed below the maximum listed value for all dose values. The collector-emitter saturation voltage stayed fairly constant thought out the irradiation process.

6. Conclusion

The 2N2222s experienced gain degradation. After 30.1 krad(Si) the forward-current transfer ratio 1 and the second collector-emitter saturation voltages remained in within the range specified by the data sheet. Forward-current transfer ratio 2 and 3 fell below specifications after 30.1 krad(Si). The forward-current transfer ratio 4 experience gain degradation for the first few doses. Then the gain had sharp increase, which was then followed by a gain degradation. This caused the upper limit of the 99/90 tolerance level to be greater than the maximum forward-current transfer ratio 4 on the data sheet between a dose of 5 krad(Si) and 19.09 krad(Si). After the dose of 19.09 krad(Si) the upper 99/90 tolerance limit was below the specification maximum. The lower limit of 99/90 tolerance level for the forward-current transfer ratio 5 was less than the minimum value stated on the data sheet for every dose, including the no dose value. Finally the first collector-emitter saturation voltage remained within specifications until 14 krad(Si).

7. References

1. Microsemi, “NPN Silicon Switching Transitor,” 2N2222 datasheet, T4-LDS-0060 Rev. 2 (100247)