

Low Dose Rate Test Results of National Semiconductor's ELDRS-free Bipolar Comparators LM111 and LM119

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Abstract—Many bipolar comparators have been shown to exhibit enhanced low dose rate sensitivity (ELDRS), where a product may have worse total ionizing dose (TID) performance when exposed to ionizing radiation at a relatively low dose rate than when exposed at a higher dose rate. This can be a significant issue for the space community where the application dose rate is typically much lower than the dose rates used to test and qualify products to a given radiation level. A characterization method has been defined in MIL-STD-883 to determine if a product could be considered to exhibit ELDRS. National Semiconductor has released new versions of the classic, and extensively studied, bipolar comparators, LM111 and LM119. These products have gone through the ELDRS characterization defined in MIL-STD-883, have been found not to exhibit ELDRS and have been rated to 100 krad(Si). The data are presented here.

Index Terms—Bipolar comparators, enhanced low dose rate sensitivity (ELDRS), LM111, LM119

I. INTRODUCTION

THE classic bipolar comparators LM111 and LM119 have been widely used in space applications and have been the subjects of many radiation studies [1]-[10]. One concern for the space community is how the products perform under ionizing radiation at relatively low dose rates [11]. The LM111 has been used extensively as a test vehicle for low dose rate studies. It has been shown that the radiation performance of the LM111 can depend upon manufacturer [1] [2], wafer processing [3], operating conditions [4], operating temperature during irradiation [5], thermal cycling prior to irradiation [6] and dose rate [1]-[3], [5], [7]-[10]. The LM119 did not show a thermal cycling dependence [6] but some versions may have dose rate dependence [10].

Due to the evolution of radiation qualification of integrated circuits and practicality, total ionizing dose (TID) testing and

qualification have been typically done at relatively high dose rates, several orders of magnitude higher than the dose rates in a space application. This is an issue for the space community as some bipolar products, such as the LM111 and LM119 can exhibit enhanced low dose rate sensitivity (ELDRS), where the electrical parametric degradation can be more pronounced at low dose rates than at high dose rate for the same TID. It had been proposed that it might be possible to simulate low dose rate (LDR) response by irradiating products at elevated temperatures at high dose (HDR) [5] but later found that this method was not valid for all product types [12]. Later it was proposed using a dose rate of 10 mrad(Si)/s with a design margin of two for the parametric drift to qualify products bipolar products for LDR environments [7]. This dose rate has been adopted for the LDR qualification in the latest revision of MIL-STD-883 (rev G) Test Method 1019 (rev. 7), released February 28, 2006 [13]. Also included in MIL-STD-883G, TM1019.7 is a characterization technique to determine if a product could be considered to have ELDRS.

National Semiconductor has recently released new space versions of the LM111 and LM119. The ELDRS characterization defined in MIL-STD-883G, TM1019.7 was demonstrated on these new products. Per the test method the products are qualified to 100 krad(Si) for LDR applications and could be considered to be "ELDRS-free".

II. PRODUCTS TESTED

The products tested are National Semiconductor's space versions of the bipolar single comparator, LM111 [14][15] and the bipolar dual comparator LM119 [16][17]. They were manufactured in National Semiconductor's UK 6 inch wafer fab using a unique process flow. National Semiconductor part numbers, the Defense Supply Center Columbus (DSCC) Standard Microcircuit Drawing (SMD) numbers, where "x" is a variable for the package type and the wafer lot numbers tested are listed in Table 1. The data are only applicable to the

TABLE I
PRODUCT NAMES AND WAFER LOT NUMBERS OF UNITS TESTED
THE SMALL "X" IS A VARIABLE FOR THE PACKAGE TYPE

National Part Number	DSCC SMD Number	Lot Number
LM111xRLQMLV	5962R0052402VxA	JM075X24
LM119xRLQMLV	5962R9679802VxA	JM086X43

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part numbers listed, as the wafer process is not used on other versions or assurance levels of these products.

The LM111 units were assembled in 14 lead ceramic Dual Inline Packages (DIP) and the LM119 units were assembled in ceramic 16 lead DIPs, according to the class V (space) flow in MIL-PRF-38535 [18]. All units received burn-in per the class V flow. It has been reported that the radiation performance of some products can depend upon whether or not the product receives burn-in [6].

III. TEST METHOD

Radiation testing was done using the ELDRS characterization in MIL-STD-883, Test Method 1019.7, section 3.13.1.1 as a guide, using a cobalt-60 gamma radiation source. A four way split was run with units biased and unbiased during irradiation at LDR and HDR. The conditions used for irradiation and the number of units analyzed are shown in Table II. The units came from 3 wafers from the same wafer lot for each product.

The HDR irradiation was done between 32 and 38 rad(Si)/s at National Semiconductor's radiation facility in South Portland, Maine. The LDR irradiation was done at 10 mrad(Si)/s at White Sands Missile Range (WSMR).

TABLE II
TEST CONDITIONS FOR THE FOUR WAY SPLIT

Dose Condition	Dose Rate		Bias Condition	Wafers	Units
	LM111 (rad(Si)/s)	LM119 (rad(Si)/s)			
LDR	0.01	0.01	Biased	3	15
LDR	0.01	0.01	Unbiased	3	15
HDR	38	32	Biased	3	18
HDR	38	32	Unbiased	3	18

The unbiased units had all leads tied to ground during irradiation. For the bias test legs on the LM111, the supply pins were held at ± 15 V, the output pulled to the 15 V rail through a 10 k Ω resistor, the balance pin pulled down to the -15 V rail through a 1 M Ω resistor and the input pins were grounded. For the bias test legs on the LM119, the supply pins were held at ± 15 V, the input pins were grounded and the output pins were left floating.

Electrical testing was done with an LTX77 test system at National Semiconductor's South Portland radiation facility. All datasheet and SMD parameters were tested [14]-[17]. For the HDR legs testing was done at 0, 3, 10, 30, 50, 80 and 100 krad(Si) levels. The LDR legs were pulled at close to the same levels, but not always exactly at those levels. For instance, on the LM119, the 50 krad(Si) level was actually tested at 53 krad(Si). LDR testing was taken out to 99 krad(Si) for the LM111 and 104 krad(Si) for the LM119, which is within the $\pm 10\%$ limit for 100 krad(Si) qualification as allowed by MIL-STD-883G, TM1019.7. For the HDR legs, electrical testing was completed within an hour of being removed from the gamma radiation. The LDR legs were shipped overnight from the test facility at WSMR to National

for testing, and shipped back overnight to WSMR to resume irradiation. Testing time limits were in accordance with MIL-STD-883G, TM1019.7.

IV. RESULTS

A. ELDRS Characterization

The ELDRS characterization results are summarized in Tables III and IV. For each parametric test, the median parametric drift was calculated from the 0 rad test point to the maximum irradiation level test point, which was 100 krad(Si) for all HDR test legs and 99 krad(Si) at LDR for the LM111 and 104 krad(Si) at LDR for the LM119. Many of the parameters were tested under a number of different conditions. The results shown in Tables III and IV are for the conditions that resulted in the greatest parametric drift. The ratio of the LDR to HDR median drift is shown in the next two columns. The last two columns in the tables indicate if any of the LDR test results were outside the pre irradiation datasheet and SMD limits. Per MIL-STD-883G, Test Method 1019.7, section 3.13.1.1, if, for any parameters, the ratio of the median LDR drift to the median HDR drift is greater than 1.5 and the parametric reading is outside the pre irradiation test limits, the "part is considered to be ELDRS susceptible" [13]. No parameters meet both conditions and the products do not meet the definition of being ELDRS susceptible.

B. LM111 Test Results

The LM111 passed TID testing at LDR to a TID level of 100 krad(Si) with all parameters inside the post irradiation limits in the datasheet and SMDs [14]-[15]. It passed HDR testing at 50 krad(Si) but failed at 80 krad(Si). The LM111xRLQMLV (SMD 5962R0052402VxA) is qualified to 100 krad(Si) for low dose rate environments, but is not qualified for high dose rate environments. For HDR environments, the original space qualified product, LM111xLQMLV (SMD 5962L0052401VxA), is qualified to 50 krad(Si) at HDR, but may have ELDRS [1]-[3].

Table V lists the average parametric readings at 0 rad for the 15 units from the LDR biased test leg, along with the average parametric drift (Ave.) and the standard deviation (σ) of the parametric drift through 99 krad(Si) for the 15 units in the two LDR test legs and 100 krad(Si) for the 18 units in the two HDR test legs. The last column lists the post irradiation specification range. The average parametric readings for the HDR and LDR test legs at each of the radiation test points are plotted for various tests in Figs. 1 to 6.

The parameter to show the most significant drift at LDR was input bias current (Fig. 1), but the LDR drift was less than the HDR drift.

At HDR, significant drift was seen for output leakage (Fig. 2). The biased condition was the worst case and the drift at HDR was ten times greater than the drift at LDR. The drift for the unbiased legs was insignificant.

The input offset current for the biased HDR leg drifted out of spec at 80 krad(Si) before recovering back to below the

TABLE III
LM111xRLQMLV ELDRS CHARACTERIZATION

Parameter	Conditions $V_{CC}=\pm 15\text{ V}$, $V_{CM}=0$ unless otherwise noted	Units	Median Drift				LDR/HDR		LDR outside pre	
			LDR		HDR		Drift Ratio		rad limits?	
			Bias	Unbias	Bias	Unbias	Bias	Unbias	Bias	Unbias
Supply Current +		mA	-0.033	-0.037	-0.010	-0.029	3.22	1.27	No	No
Supply Current -		mA	0.028	0.030	0.012	0.029	2.24	1.03	No	No
Input Offset Voltage	$V_I=0$	mV	0.091	-0.028	0.056	-0.070	1.64	0.39	No	No
Input Offset Voltage	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	mV	0.092	-0.026	0.049	-0.070	1.88	0.38	No	No
Input Offset Current	$V_I=0$	nA	0.39	0.59	5.88	0.49	0.07	1.20	No	No
Input Offset Current	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	nA	1.27	0.69	8.63	0.88	0.15	0.78	No	No
Input Bias Current+	$V_I=0$	nA	-78.3	-78.2	-80.7	-104.3	0.97	0.75	Yes	Yes
Input Bias Current-	$V_I=0$	nA	-78.6	-79.1	-87.1	-104.9	0.90	0.75	Yes	Yes
Input Bias Current+	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	nA	-96.8	-101.7	-100.4	-133.7	0.96	0.76	Yes	Yes
Input Bias Current-	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	nA	-97.5	-102.9	-109.8	-134.5	0.89	0.76	Yes	Yes
Gain+		V/mV	-10.04	-13.45	-9.08	-13.82	1.11	0.97	No	No
Gain-		V/mV	-8.33	-11.50	-7.75	-13.44	1.08	0.86	No	No
Input Leakage Current	$V_I=-17/+12\text{ V}$, $V_{CC}=\pm 18\text{ V}$	nA	0.28	0.06	0.79	0.06	0.36	0.99	No	No
Output Leakage Current	$V_O=32\text{ V}$, $V_{CC}=\pm 18\text{ V}$	nA	9.02	0.06	135.84	0.21	0.07	0.29	Yes	No

TABLE IV
LM1119xRLQMLV ELDRS CHARACTERIZATION

Parameter	Conditions $V_{CC}=\pm 15\text{ V}$, $V_{CM}=0$ unless otherwise noted	Units	Median Drift				LDR/HDR		LDR outside pre	
			LDR		HDR		Drift Ratio		rad limits?	
			Bias	Unbias	Bias	Unbias	Bias	Unbias	Bias	Unbias
Supply Current +		mA	-0.058	-0.010	-0.178	-0.053	0.32	0.18	No	No
Supply Current -		mA	0.049	0.031	0.049	0.026	1.02	1.18	No	No
Input Offset Voltage Ch. 1	$V_{CM}=12\text{ V}$	mV	0.020	0.047	0.007	0.007	2.96	7.00	No	No
Input Offset Voltage Ch. 2	$V_{CM}=12\text{ V}$	mV	-0.001	0.007	0.038	-0.009	-0.03	-0.79	No	No
Input Offset Voltage Ch. 1	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	mV	-0.012	-0.004	-0.019	-0.032	0.60	0.13	No	No
Input Offset Voltage Ch. 2	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	mV	-0.035	-0.035	-0.043	-0.048	0.82	0.73	No	No
Input Offset Current Ch. 1	$V_{CM}=12\text{ V}$	nA	-6.52	-12.66	-1.84	-5.45	3.54	2.32	No	No
Input Offset Current Ch. 2	$V_{CM}=12\text{ V}$	nA	-2.75	-5.64	-2.30	-1.23	1.19	4.59	No	No
Input Offset Current Ch. 1	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	nA	-3.80	-8.14	1.84	0.77	-2.06	-10.61	No	No
Input Offset Current Ch. 2	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	nA	-1.54	-4.13	-0.77	0.15	2.01	-26.95	No	No
Input Bias Current Ch. 1		μA	0.094	0.137	0.086	0.128	1.10	1.07	No	Yes
Input Bias Current Ch. 2		μA	0.094	0.139	0.084	0.127	1.12	1.10	No	Yes
Input Bias Current Ch. 1	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	μA	0.078	0.121	0.064	0.109	1.22	1.11	No	No
Input Bias Current Ch.2	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	μA	0.079	0.123	0.063	0.108	1.26	1.14	No	No
Gain Ch. 1	$V_{CC}=5/0\text{ V}$, $\Delta V_O=4.5\text{ V}$	V/mV	-2.38	-2.42	-1.30	-1.49	1.83	1.62	No	No
Gain Ch. 2	$V_{CC}=5/0\text{ V}$, $\Delta V_O=4.5\text{ V}$	V/mV	-1.40	-1.62	-1.53	-1.75	0.92	0.92	No	No
Output Leakage Current Ch. 1	$V_{CC}=15/-1\text{ V}$, $V_{Gnd}=0$, $V_O=35\text{ V}$	μA	0.014	0.006	0.026	-0.009	0.55	-0.69	No	No
Output Leakage Current Ch. 2	$V_{CC}=15/-1\text{ V}$, $V_{Gnd}=0$, $V_O=35\text{ V}$	μA	-0.011	-0.020	-0.012	0.029	0.93	-0.69	No	No

spec limit at 100 krad(Si) (Fig. 3). For a parameter that compares sections of a product, such as input offset current, a non monotonic drift can be common. One of the two input transistors may drift more at the lower dose, causing a higher input offset current. Then at the higher doses, the other input transistor may begin to drift, so that the two transistors match better at the higher TID, lowering the input offset current. This illustrates why it is important to test a product at the interim dose levels and not just at the final rated dose.

For the HDR test legs, there were two parameters (input offset voltage and input bias current) where the median and average values were within the specification limits, but individual units were outside the limits at 80 or 100 krad(Si).

C. LM119 Test Results

The LM119xRLQMLV (SMD 5962R9679802VxA) passed all TID testing to a level of 100 krad(Si) with all parameters inside the post irradiation limits in the datasheets and SMDs

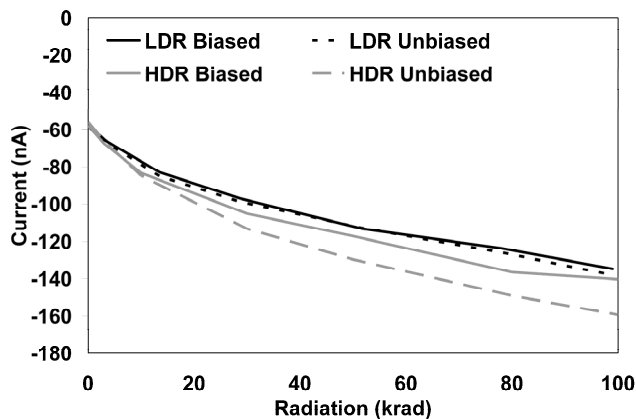


Fig. 1 LM111 Input bias current vs. radiation exposure for the positive input. $V_{CC}=\pm 15\text{ V}$. Pre irradiation limit is -100 nA and post irradiation limit is -180 nA.

TABLE V
LM111xRLQMLV DRIFT AVERAGE (AVE.) AND STANDARD DEVIATION (σ)

Parameter	Conditions $V_{CC}=\pm 15\text{ V}$, $V_{CM}=0$ unless otherwise noted	Units	0 rad	LDR Drift through 99 krad(Si)				HDR Drift through 100 krad(Si)				Spec Range
			Ave.	Bias		Unbias		Bias		Unbias		
			Value	Ave.	σ	Ave.	σ	Ave.	σ	Ave.	σ	
Supply Current +		mA	3.134	-0.034	0.011	-0.037	0.005	-0.011	0.007	-0.037	0.015	6
Supply Current -		mA	-2.104	0.025	0.009	0.031	0.005	0.013	0.006	0.033	0.010	6
Input Offset Voltage	$V_I=0$	mV	-0.186	0.076	0.045	-0.033	0.027	0.039	0.055	-0.083	0.039	6
Input Offset Voltage	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	mV	-0.217	0.076	0.044	-0.032	0.025	0.033	0.053	-0.081	0.035	6
Input Offset Current	$V_I=0$	nA	0.51	0.44	0.42	0.57	0.59	5.72	1.26	0.63	0.69	20
Input Offset Current	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	nA	0.68	1.14	0.58	0.76	0.81	8.49	1.82	0.83	0.82	20
Input Bias Current+	$V_I=0$	nA	-57.3	-77.4	4.5	-79.7	6.1	-82.4	5.9	-103.7	7.6	180
Input Bias Current-	$V_I=0$	nA	-57.8	-77.8	4.3	-80.2	6.1	-88.1	5.9	-104.3	7.7	180
Input Bias Current+	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	nA	-72.4	-95.9	5.5	-103.7	8.2	-102.6	8.1	-133.4	9.8	225
Input Bias Current-	$V_I=0$, $V_{CC}=29.5/-0.5\text{ V}$, $V_{CM}=-14.5\text{ V}$	nA	-73.1	-97.1	5.2	-104.4	8.2	-111.1	8.0	-134.2	9.9	225
Gain+		V/mV	104.32	-10.76	3.68	-13.69	2.73	-9.04	4.09	-14.22	2.55	
Gain-		V/mV	97.62	-8.80	3.03	-11.42	2.24	-8.04	4.97	-12.78	2.07	
Input Leakage Current	$V_I=-17/+12\text{ V}$, $V_{CC}=\pm 18\text{ V}$	nA	-0.28	0.28	0.03	0.07	0.04	0.78	0.25	0.06	0.02	500
Output Leakage Current	$V_O=32\text{ V}$, $V_{CC}=\pm 18\text{ V}$	nA	0.82	9.54	2.61	0.08	0.09	126.82	63.37	0.22	0.10	25

TABLE VI
LM1119xRLQMLV DRIFT AVERAGE (AVE.) AND STANDARD DEVIATION (σ)

Parameter	Conditions $V_{CC}=\pm 15\text{ V}$, $V_{CM}=0$ unless otherwise noted	Units	0 Rad	LDR Drift through 104 krad(Si)				HDR Drift through 100 krad(Si)				Spec Range
			Ave.	Bias		Unbias		Bias		Unbias		
			Value	Ave.	σ	Ave.	σ	Ave.	σ	Ave.	σ	
Supply Current +		mA	8.114	-0.048	0.008	-0.001	0.010	-0.169	0.010	-0.054	0.020	11
Supply Current -		mA	-3.070	0.061	0.002	0.039	0.005	0.048	0.002	0.032	0.004	4.5
Input Offset Voltage Ch. 1	$V_{CM}=12\text{ V}$	mV	0.202	0.031	0.010	0.054	0.017	0.021	0.009	0.015	0.009	8
Input Offset Voltage Ch. 2	$V_{CM}=12\text{ V}$	mV	-0.140	0.007	0.010	0.010	0.022	0.016	0.009	0.000	0.047	8
Input Offset Voltage Ch. 1	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	mV	-0.370	-0.013	0.007	-0.008	0.010	-0.014	0.007	-0.033	0.006	8
Input Offset Voltage Ch. 2	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	mV	-0.291	-0.037	0.006	-0.043	0.013	-0.027	0.006	-0.046	0.039	8
Input Offset Current Ch. 1	$V_{CM}=12\text{ V}$	nA	-7.69	-5.11	1.09	-13.52	3.11	-1.60	1.57	-6.57	2.24	300
Input Offset Current Ch. 2	$V_{CM}=12\text{ V}$	nA	-3.69	-3.23	1.20	-6.53	2.40	-0.66	1.45	-3.47	8.21	300
Input Offset Current Ch. 1	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	nA	-0.76	-2.59	0.87	-8.43	2.39	2.66	2.70	-0.72	3.42	300
Input Offset Current Ch. 2	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	nA	-1.03	-1.60	0.87	-4.48	1.85	0.96	1.53	-1.76	6.94	300
Input Bias Current Ch. 1		μA	0.365	0.095	0.002	0.156	0.020	0.099	0.003	0.145	0.004	1
Input Bias Current Ch. 2		μA	0.369	0.096	0.003	0.158	0.018	0.099	0.004	0.152	0.029	1
Input Bias Current Ch. 1	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	μA	0.326	0.076	0.002	0.138	0.019	0.076	0.003	0.125	0.004	1
Input Bias Current Ch.2	$V_{CC}=5/0\text{ V}$, $V_{CM}=1\text{ V}$	μA	0.328	0.077	0.002	0.140	0.018	0.077	0.003	0.131	0.028	1
Gain Ch. 1	$V_{CC}=5/0\text{ V}$, Delta $V_O=4.5\text{ V}$	V/mV	35.04	-2.89	0.32	-2.89	0.55	-1.64	0.17	-1.70	0.26	
Gain Ch. 2	$V_{CC}=5/0\text{ V}$, Delta $V_O=4.5\text{ V}$	V/mV	36.96	-1.82	0.13	-1.85	0.32	-1.79	0.15	-1.93	0.17	
Output Leakage Current Ch. 1	$V_{CC}=15/-1\text{ V}$, $V_{Gnd}=0$, $V_O=35\text{ V}$	μA	0.181	0.026	0.039	-0.009	0.043	0.006	0.044	-0.009	0.050	1.8
Output Leakage Current Ch. 2	$V_{CC}=15/-1\text{ V}$, $V_{Gnd}=0$, $V_O=35\text{ V}$	μA	0.208	0.004	0.034	-0.008	0.052	0.004	0.036	0.010	0.036	1.8

[16]-[17]. The LM119xRLQMLV (5962R9679802VxA) is rated to 100 krad(Si) for both low dose rate and high dose rate environments.

Table VI lists the average parametric readings at 0 rad for the 15 units from the LDR biased test leg, along with the average parametric drift (Ave.) and the standard deviation (σ) of the parametric drift through 104 krad(Si) for the 15 units in the two LDR test legs and 100 krad(Si) for the 18 units in the two HDR test legs. The last column lists the post irradiation specification range. The average parametric readings for the HDR and LDR test legs at each of the radiation test points are plotted for various tests in Figs. 7 to 12. All plots are for channel 1, which generally had the greater average parametric drift of the two channels.

In general, the LM119xRLQMLV had less parametric drift than the LM111xRLQMLV. The parameter to show the most significant drift relative to the specification range was input

bias current (Fig. 7).

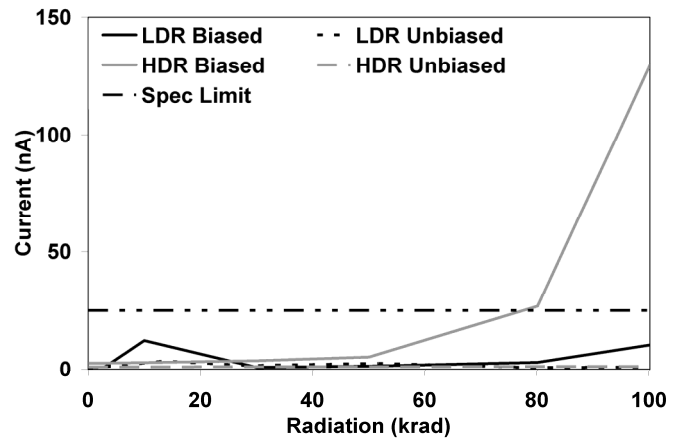


Fig. 2 LM111 Output leakage vs. radiation exposure. $V_O=32\text{ V}$, $V_{CC}=\pm 18\text{ V}$ Pre irradiation limit is 10 nA and post irradiation limit is 25 nA.

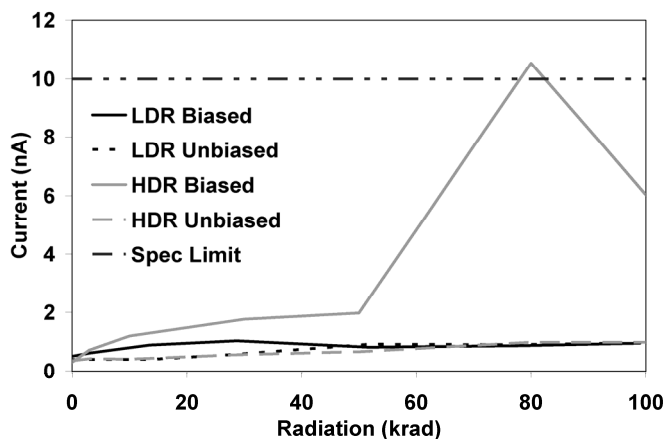


Fig. 3 LM111 Input offset current vs. radiation exposure. $V_{CM}=14.5$ V and $V_{CC}=29.5$ V/ -0.5 V. Pre and post irradiation limits are ± 10 nA.

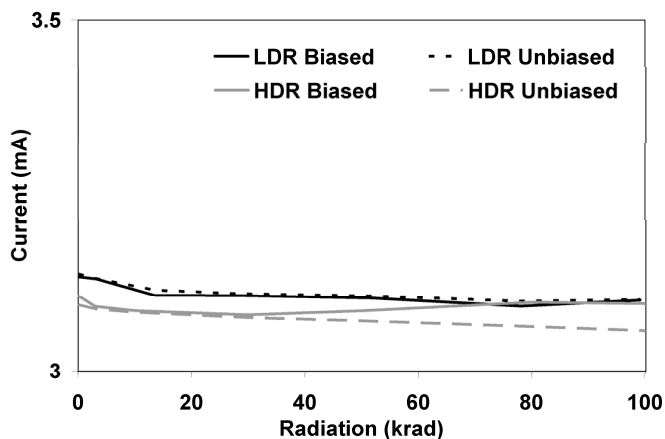


Fig. 5 LM111 Supply current vs. radiation exposure. $V_{CC}=\pm 15$ V. Pre and post irradiation maximum limit is 6 mA.

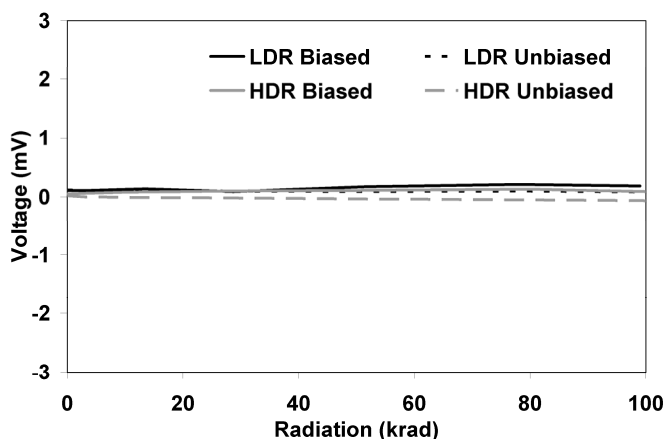


Fig. 4 LM111 Input offset voltage vs. radiation exposure. $V_{CC}=\pm 15$ V, $V_{CM}=0$ and $V_I=0$. Pre and post irradiation limits are ± 3 V.

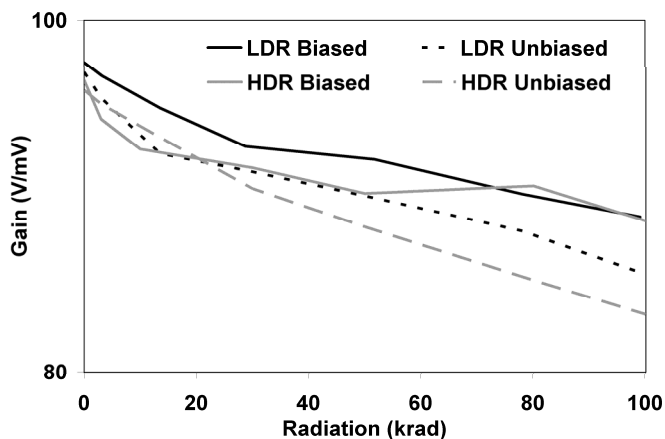


Fig. 6 LM111 Gain vs. radiation exposure. $V_{CC}=\pm 15$ V. Pre and post irradiation minimum limit is 10 V/mV.

TABLE VII
LM1119xRLQMLV WITHIN WAFER, WAFER TO WAFER AND LOT TO LOT DRIFT VARIATION FOR BIASED LDR TEST LEG

Parameter	Conditions $V_{CC}=\pm 15$ V, $V_{CM}=0$ unless otherwise noted	Units	0 Rad	Ave.	Standard Deviation			Spec Range
			Value	104 krad	Across Wafer	Across 1 Lot	Across 2 Lots	
Supply Current +		mA	8.114	-0.048	0.010	0.008	0.033	11
Supply Current -		mA	-3.070	0.061	0.002	0.002	0.011	4.5
Input Offset Voltage Ch. 1	$V_{CM}=12$ V	mV	0.202	0.031	0.011	0.010	0.098	8
Input Offset Voltage Ch. 2	$V_{CM}=12$ V	mV	-0.140	0.007	0.007	0.010	0.058	8
Input Offset Voltage Ch. 1	$V_{CC}=5/0$ V, $V_{CM}=1$ V	mV	-0.370	-0.013	0.006	0.007	0.046	8
Input Offset Voltage Ch. 2	$V_{CC}=5/0$ V, $V_{CM}=1$ V	mV	-0.291	-0.037	0.006	0.006	0.058	8
Input Offset Current Ch. 1	$V_{CM}=12$ V	nA	-7.69	-5.11	1.09	1.09	6.79	300
Input Offset Current Ch. 2	$V_{CM}=12$ V	nA	-3.69	-3.23	1.06	1.20	3.86	300
Input Offset Current Ch. 1	$V_{CC}=5/0$ V, $V_{CM}=1$ V	nA	-0.76	-2.59	1.01	0.87	2.81	300
Input Offset Current Ch. 2	$V_{CC}=5/0$ V, $V_{CM}=1$ V	nA	-1.03	-1.60	0.82	0.87	2.10	300
Input Bias Current Ch. 1		μ A	0.365	0.095	0.002	0.002	0.014	1
Input Bias Current Ch. 2		μ A	0.369	0.096	0.001	0.003	0.015	1
Input Bias Current Ch. 1	$V_{CC}=5/0$ V, $V_{CM}=1$ V	μ A	0.326	0.076	0.002	0.002	0.009	1
Input Bias Current Ch.2	$V_{CC}=5/0$ V, $V_{CM}=1$ V	μ A	0.328	0.077	0.001	0.002	0.010	1
Gain Ch. 1	$V_{CC}=5/0$ V, $\Delta V_O=4.5$ V	V/mV	35.04	-2.89	0.37	0.32	1.42	
Gain Ch. 2	$V_{CC}=5/0$ V, $\Delta V_O=4.5$ V	V/mV	36.96	-1.82	0.30	0.13	0.67	
Output Leakage Current Ch. 1	$V_{CC}=15/-1$ V, $V_{Gnd}=0$, $V_O=35$ V	μ A	0.181	0.026	0.053	0.039	0.045	1.8
Output Leakage Current Ch. 2	$V_{CC}=15/-1$ V, $V_{Gnd}=0$, $V_O=35$ V	μ A	0.208	0.004	0.026	0.034	0.032	1.8

D. Unit, Wafer and Lot Drift Variations

For the LM119xRLQMLV, variations in unit to unit, wafer to wafer and wafer lot to wafer lot parametric drifts are shown in Table VII for LDR with the units biased during irradiation. The first two data columns list the average parametric values at 0 rad and the average parametric drift between 0 and 104 krad(Si) for the 15 units from the three wafers used in the ELDRS characterization. The next column lists the standard deviation of the parametric drift for 5 units from one wafer. The “Across 1 Lot” column lists standard deviation of the parametric drift for the 15 units from the three wafers used in the ELDRS characterization. The “Across 2 Lots” column lists the standard deviation of the parametric drift for the units from the ELDRS characterization lot plus 30 units from 6 wafers from a second wafer lot.

The standard deviations indicate that there is little variation in parametric drift within a wafer or across a wafer lot, while there is more variation from wafer lot to wafer lot. For many parameters, there was more variation in drift seen between the two channels than there was across the wafer lot for one channel. For both lots tested, channel 1 had greater parametric drift than channel 2 for most parameters.

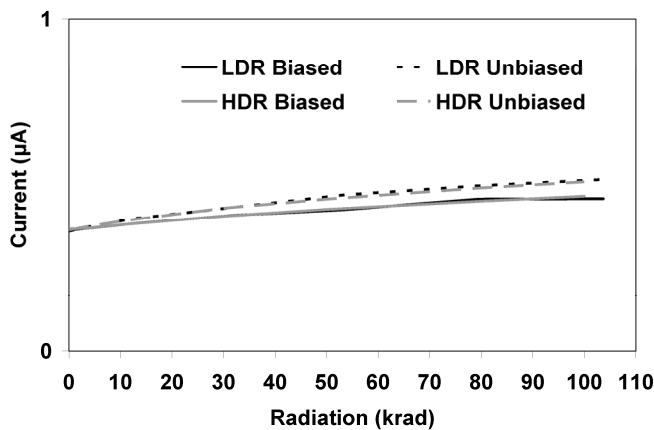


Fig. 7 LM119 Input bias current vs. radiation exposure for the positive input of channel 1. $V_{CC}=\pm 15$ V, $V_{CM}=0$. The pre irradiation limit is 4.75 μ A and the post irradiation limit is 1 μ A.

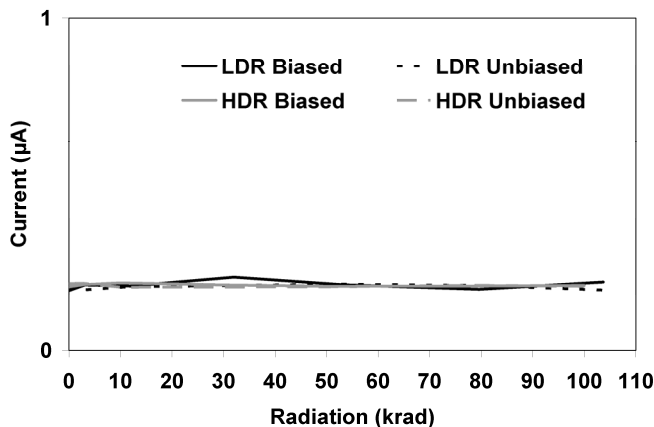


Fig. 8 LM119 Output leakage vs. radiation exposure for channel 1. The pre and post irradiation maximum limit is 1.8 μ A.

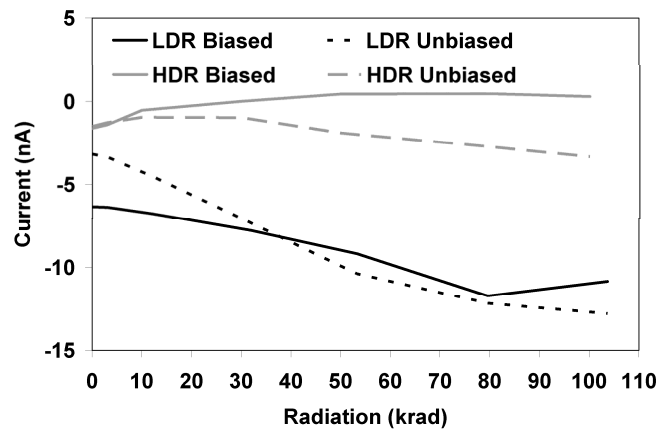


Fig. 9 LM119 Input offset current vs. radiation exposure for channel 1. $V_{CC}=\pm 15$ V, $V_{CM}=0$. Pre irradiation limit is ± 75 nA and the post irradiation limit is ± 150 nA.

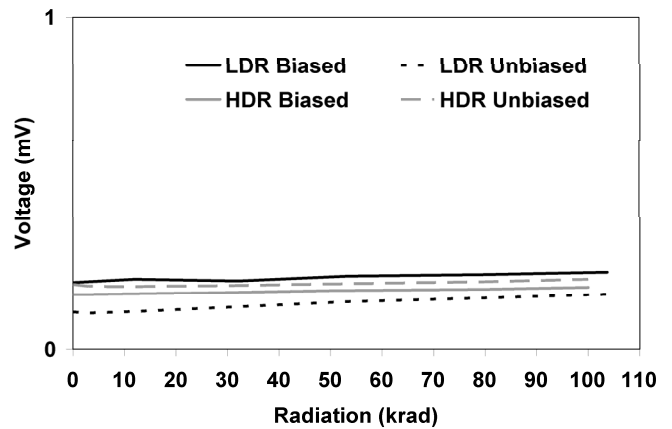


Fig. 10 LM119 Input offset voltage vs. radiation exposure for channel 1. $V_{CC}=\pm 15$ V, $V_{CM}=\pm 12$ V. Pre irradiation limit is ± 3.8 V and post irradiation limit is ± 4 V.

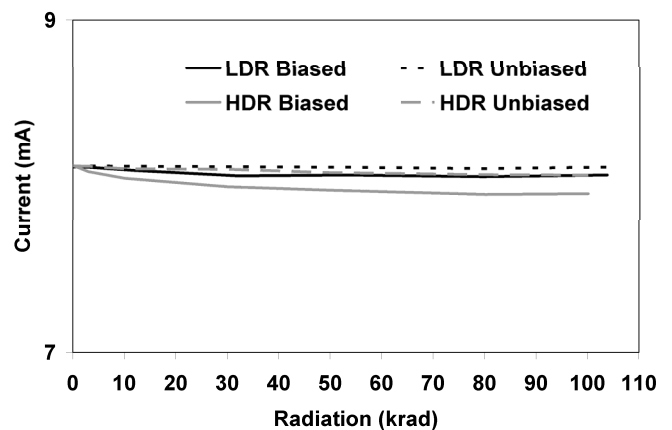


Fig. 11 LM119 Supply current vs. radiation exposure. $V_{CC}=\pm 15$ V. Pre and post maximum limit is 11 mA.

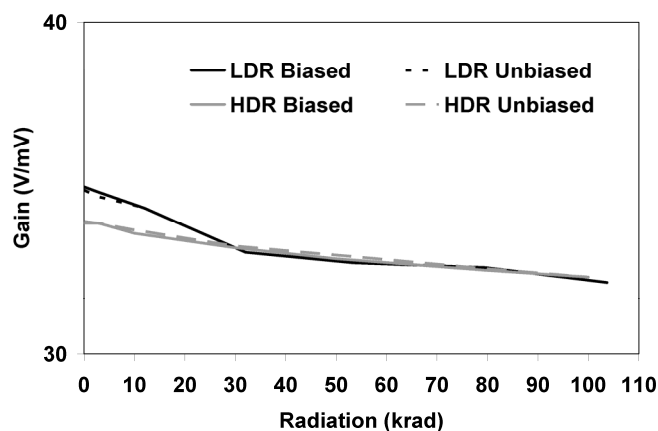


Fig. 12 LM119 Gain vs. radiation exposure for channel 1. Delta $V_o=4.5$ V, $V_{CC}=5/0$ V. Pre and post irradiation minimum limit is 10.5 V/mV.

V. CONCLUSIONS

National Semiconductor's LM111xRLQMLV (SMD 5962R0052402VxA) and LM119xRLQMLV (SMD 5962R9679802VxA) can be considered "ELDRS-free" per the ELDRS characterization method in MIL-STD-883G, Test Method 1019.7.

For the LM111xRLQMLV, the radiation performance at low dose rate (LDR) is significantly better than at high dose rate (HDR). The product is qualified to 100 krad(Si) for LDR environments but is not qualified for HDR environments. A separate part, LM111xLQMLV (SMD 5962L0052401VxA), is qualified for HDR environments to 50 krad(Si), but it may exhibit ELDRS.

The radiation performance for the LM119xRLQMLV was relatively the same for both LDR and HDR and the product is rated to 100 krad(Si) for both LDR and HDR environments.

Both products are over 30 years old and have historic, industry standard parametric limits. In general, the parametric drift though radiation at LDR is relatively minor compared to the historic parametric specification limit range.

At HDR, some units of the LM111xRLQMLV failed at 80 krad(Si), but passed at 100 krad(Si). Not all electrical parameters will have a monotonic degradation through radiation exposure. To ensure that the product performance will remain with the specified limits throughout an entire mission, it is necessary to test and qualify the product at interim radiation test points, and not just at the TID rated level.

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