Metodologia per la scelta di componentistica non rad-hard in missioni spaziali e verifica sperimentale

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Che componentistica utilizzare in missioni con bassi livelli di radiazioni: total dose: tra i 2 e i 15Krad Latch-up: >36MeVcm2/mg

Obbiettivo:

Soddisfare i requisiti della missione utilizzando componentistica non rad hard con un buon grado di confidenza

Selezione dei componenti:

- Resistenza alle radiazioni
- Livello di qualità
- Caratteristiche design

NB: non c'è nessuna garanzia sul lotto di produzione

Esistono data base in web
NASA http://radhome.gsfc.nasa.gov/top.htm
ESA https://escies.org/splash.html
ERRIC http://erric.dasiac.com/
NASA JPL http://radnet.jpl.nasa.gov/cgi-win/1/FrontPage_CGI_Project?|main

Contenuti

- Test di Total Dose
- Latch-up
- Single Events Upset
- Single Events Transient

JPL DATA BASE: Heavy Ions Test.

Test Org.*	Device	Function	Technology	Mfr.	Effective SEU LET* Threshold	Device Xsection (cm^2)	Bits Tested	Bit Xsection (cm^2)	Test Date	LUth	LU Xsection (cm^2)	Fac.
	Note: Entries in **RED** indicate data added since the 1997 Compendium.											
MMS	ULA 5N104	ASIC (Bus)	Bipolar	FER	<5.5	2.0E-03			1992	>88		
JPL	UT1553BCRTM	Bus Controller	CMOS/epi	UTM	60				May-91	>120		
		DAC (8-bit)										
BREL	AD558		Bipolar-IIL	ADI	<<5	2.0E-04			Feb-92			
JPL	AD7225TQ		LCCMOS	ADI					Jan-97	>62		TAM
MM	CA3338AD		CMOS/TTL	HAR	>119				May-93			
GSFC	DAC08AQ		Bipolar	PMI	~3.5	2.0E-02			Jul-94			
S^3	DAC8408		CMOS	PMI	45	4.0E-05			Jan-92			
GSFC	DAC8800	Octal, serial input		ADI	>80				Apr-97	>80		
		DAC (10-bit)										
JPL	AD7533		CMOS	ADI					Nov-92	>120		
JPL	MP7533		CMOS	MPS					Nov-92	>120		

Dati, in un report NASA, sul dispositivo elettronico testato :

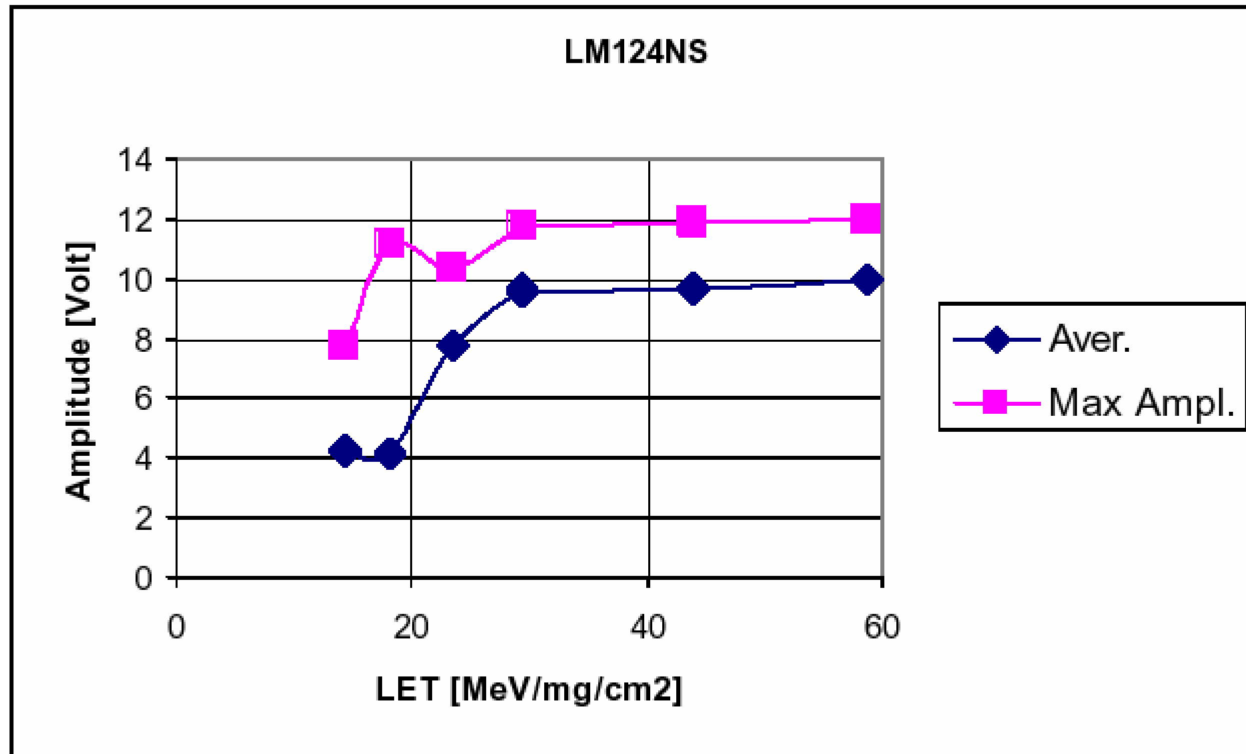
TABLE I. Part Information

Generic Part Number:	PM139
GOES ITT Part Number	PM139
Charge Number:	C80709
Manufacturer:	Analog Devices
Lot Date Code (LDC):	9720A
Quantity Tested:	11
Serial Number of Control Samples:	256, 261, 262
Serial Numbers of Radiation Samples:	254, 255, 257, 258, 259, 260, 263, and 264
Part Function:	Quad Low Power, Precision Comparator
Part Technology:	Bipolar
Package Style:	14-Pin DIP
Test Equipment:	A540/Bench Tests
Test Engineer:	S. Archer-Davies

Misure dei parametri a vari step di total dose

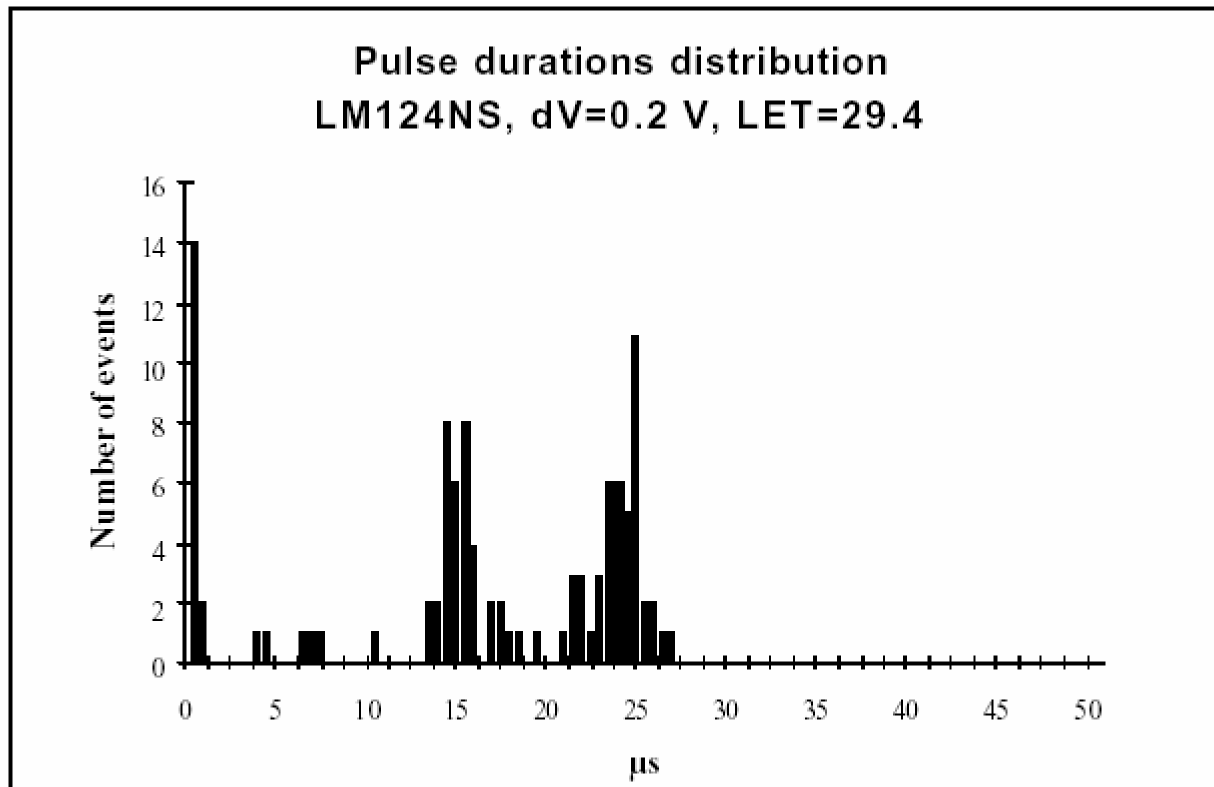
Test			Spec. Lim. /2		Initial		Total Dose Exposure (kRads Si) 20.0		40.0		60.0		80.0	
#	Parameters	Units	min	max	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1	+Icc	mA	0	2.0	0.7	0.05	0.7	0.1	0.6	0.1	0.6	0.1	0.6	0.1
2	-Icc	mA	0	3.0	0.8	0	0.8	0.05	0.7	0.1	0.7	0.1	0.7	0.1
3-6	VOS_5V	mV	-5.0	5.0	0.2	0	0.2	0	0.2	0	0.2	0	0.2	0
7-10	VOS_30V	mV	-5.0	5.0	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1
11-14	PSRR	dB	70		98	9	98	8	97	5	96	5	96	7
15-18	P_IIB_5V	nA	-100	-1	-31	1	-37	2	-40	3	-44	6	-44	2
19-22	N_IIB_5V	nA	-100	-1	-31	1	-37	2	-40	3	-44	6	-44	2
23-26	IIOS_5V	nA	-25	25	1	0	1	0.5	2	1	2	1	7	4
27-30	P_IIB_30V	nA	-100	-1	-31	1	-40	2	-44	2	-49	3	-45	5
31-34	N_IIB_30V	nA	-100	-1	-31	1	-40	2	-44	2	-49	3	-45	5
35-38	IIOS_30V	nA	-25	25	1	0	1	1	2	1	2	1	6	3
43-46	I_SINK	mA	8.0		19	1	19	1	18	1	18	0	18	0
47-50	V_SAT	mV		400	238	2	236	2	236	2	235	3	235	2
51-54	I_LEAK	?A		0.50	0.05	0	0.05	0	0.06	0.02	0.07	0.03	0.10	0
55-58	Open Loop Gain	dB	94		97	1	97	1	96	1	96	1	96	1

LM124 Heavy transient test
Esa report ESA_QCA0312S_C



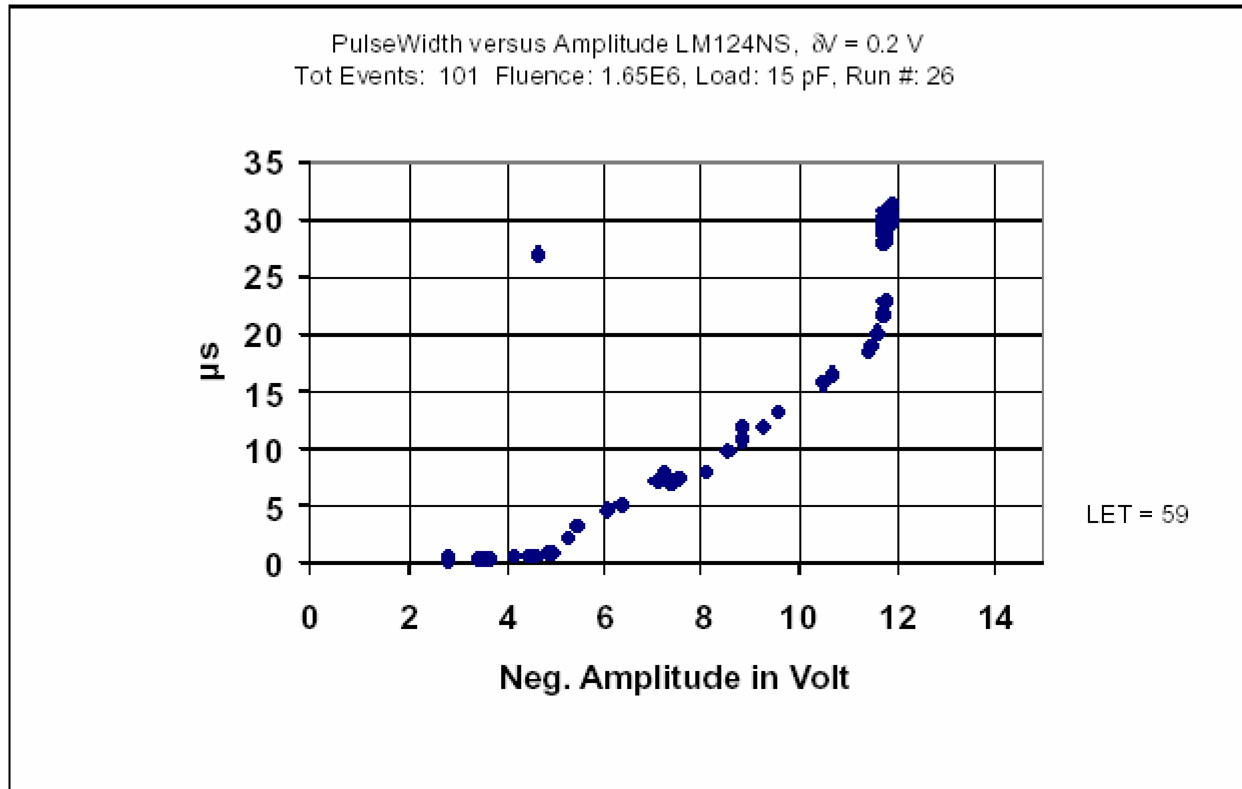
Average and Max amplitudes versus the LET-value.

LM124 Heavy transient test
Esa report ESA_QCA0312S_C. cnt.



The distribution of the events versus the pulse duration.

LM124 Heavy transient test Esa report ESA_QCA0312S_C. cnt.



Scatter diagram showing SET pulse FWHM vs. the amplitude in Volt, with delta input voltage = 0.2 V.

Attenzione:

Date code dei componenti quasi sempre non recenti.
Dalla data dei test ad oggi il componente può aver subito delle variazioni tecnologiche sul die che possono cambiare considerevolmente le sue prestazioni rispetto alla tolleranza alle radiazioni. Vediamo un esempio:

NASA Report: PPM-94-038

TABLE I. Part Information

Generic Part Number:	LM139
CASSINI/CIRS Part Number:	5962-9773901CA
CASSINI/CIRS Control Number:	[illegible]
Charge Number:	C44543
Manufacturer:	National
Lot Date Code:	9108, 9228
Quantity Tested:	10
Serial Numbers of Control Samples:	80, 81
Serial Numbers of	
Part Function:	Quad Voltage Comparator
Part Technology:	Bipolar
Package Style:	14-pin DIP
Test Equipment:	A540
Test Engineer:	T. Mondy

NASA Report: PPM-94-038 cnt.

Library/300.1

A radiation evaluation was performed on LM139 (Quad Voltage Comparator) to determine the total dose tolerance of these parts. A brief summary of the test results is provided below. For detailed information, refer to Tables I through V and Figure 1.

The total dose testing was performed using a cobalt-60 gamma ray source. During the radiation testing, ten parts were irradiated under bias (see Table V for bias configuration), ten parts were irradiated unbiased and three parts were used as control samples. The total dose radiation levels were 5, 10, 15, 20, 30, 50, 75 and 100 krads*. The dose rates were between 0.08 and 1.47 krads/hour (see Table II for radiation schedule). After the 100 krad irradiation, the parts were annealed for 168 hours at 25°C, after which the parts were annealed for 168 hours at 100°C. After each radiation exposure and annealing step, the parts were electrically tested according to the test conditions and the specification limits** listed in Table III.

→ All parts passed initial electrical measurements. All irradiated parts passed all electrical tests throughout all irradiation steps up to and including the 100 krad level.

After annealing for 168 hours at 25°C, all irradiated parts continued to pass all electrical tests.

After annealing for 168 hours at 100°C, no rebound effects were observed.

Table IV provides the mean and standard deviation values for each parameter after different irradiation exposures and annealing steps.

Any further details about this evaluation can be obtained upon request. If you have any questions, please call me at (301) 731-8954

LM139 (National semi) Total dose test
ESA report: ESA-QCA-RTR-LM139-00102

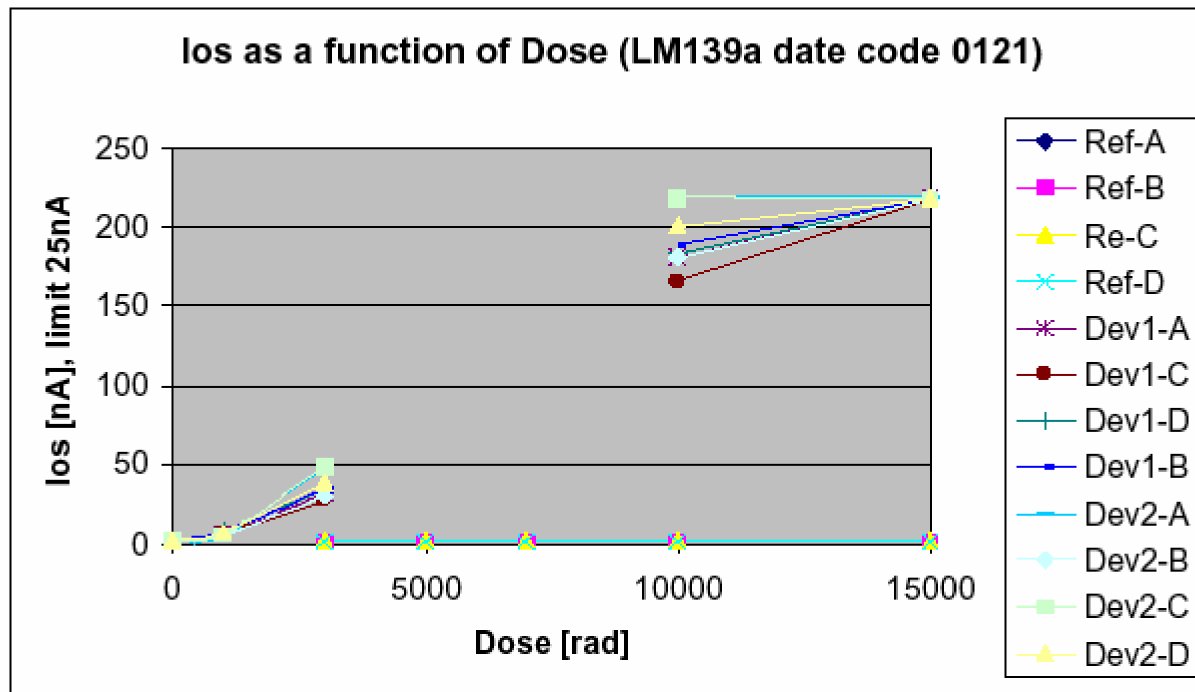


Figure 7 Ios as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

Out of specification a 3Krad!

ESA report: ESA-QCA-RTR-LM139-00102 cnt.

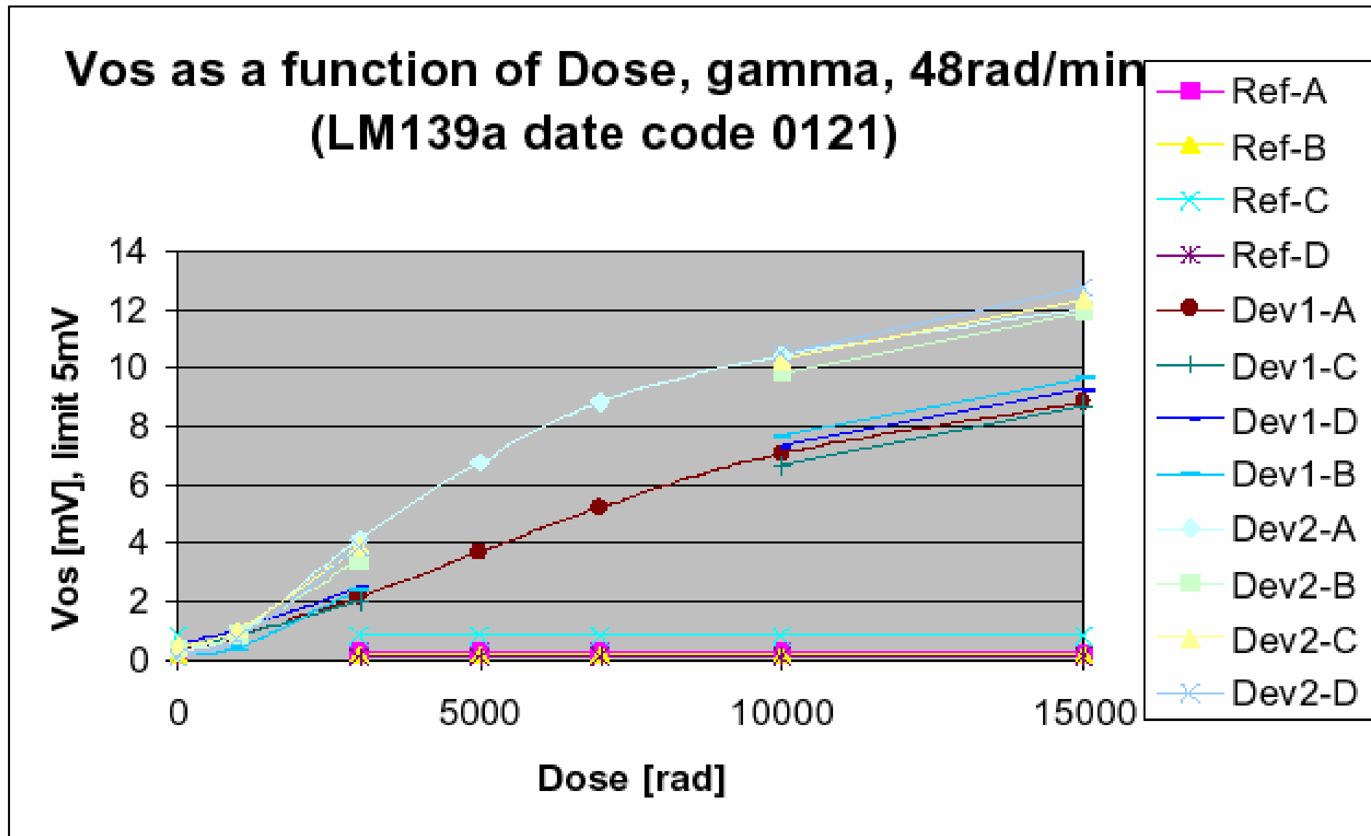


Figure 2 Vos as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

Degrado della Vos 1,5Krad

Problema: i dati di total dose del transistor 2N6796 mostrano un fuori specifica a 10Krad (GSFC NASA Report PPM-97-039)

Il requisito della missione è >10Krad.
Soluzione: eseguire dei test sul lotto acquistato
Rischio: rifiuto del lotto se il risultato dovesse essere negativo. Il costruttore ovviamente non può dare nessuna garanzia sul lotto

Dal report NASA PPM-97-039:

Generic Part Number:	2N6796
HST-486, ST M&R FOLLOW ON Part Number	JANTXV2N6796
Charge Number:	M78238
Manufacturer:	Harris
Lot Date Code (LDC):	9637
Quantity Tested:	10
Serial Number of Control Samples:	361, 362
Serial Numbers of Radiation Samples:	363, 364, 365, 366, 367, 368, 369, and 370
Part Function:	N-Channel MOSFET
Part Technology:	MOSFET
Package Style:	TO-39
Test Equipment:	CISTRONICS
Test Engineer:	D. Davis

Dal report NASA PPM-97-039 ctn.

Caratteristiche elettriche del 2N6796

Test #	Parameter	Units	Test Conditions	Spec. min	Lim. max
1	VBDSS	V	$V_{GS} = 0V$, $I_D = 1.0mA$	100	
2	VGSth	V	$V_{DS} \geq V_{GS}$, $I_D = 0.25mA$	2	4
3	IGSS	nA	$V_{DS} = 0V$, $V_{GS} = +20V$		100
4	IGSSr	nA	$V_{DS} = 0V$, $V_{GS} = -20V$		100
5	IDSS	µA	$V_{DS} = 0V$, $V_{GS} = 80\%$ rated V_{DS}		25
6	RDS on	mΩ	$V_{GS} = 10V$, pulsed /2, $I_D = 5A$		180
7	RDS on	mΩ	$V_{GS} = 10V$, pulsed /2, $I_D = 8A$		195
8	VSD	V	$V_{GS} = 0V$, $I_S = I_{D1}$, pulsed /2		1.5

Dal report NASA PPM-97-039 ctn.

Misure effettuate dopo esposizione a Total Dose

Test #	Parameters	Units	Spec. Lim. /2 min	max	Initial mean	sd	Total Dose Exposure (kRads) 5.0 mean	sd	10.0 mean	sd	Annealing 48 hours @25°C /3 mean	sd	TDE (kRads) 15.0 mean	sd
1	VBDSS /4	V	100		P		P		P		P		P	
2	VGSth	V	2	4	2.59	0.09	2.06	0.11	1.64	0.11	1.70	0.11	1.30	0.11
3	IGSS	nA		100	1.45	0.51	0.85	0.22	16.3	16.3	3.4	3.7	1.4	0.22
4	IGSSr	nA		100	1.16	0.49	1.9	0.17	17.6	16.1	3.3	3.3	0.88	0.20
5	IDSS	µA		25	0.003	0.002	0.016	0.005	0.47	0.18	0.28	0.15	2.52	1.45
6	RDS on	mΩ		180	133.6	1.4	132.2	1.2	130.0	1.3	130.6	1.33	131.9	1.19
7	RDS on	mΩ		195	135.2	1.4	133.5	1.2	131.0	1.5	131.8	1.33	133.1	1.17
8	VSD	V		1.5	0.12	0.01	1.13	0.04	1.12	0.01	1.12	0.01	1.12	0.01

Il testo è stato eseguito dalla IGG (UK)

Description

This test was performed to evaluate the performance of the component type
2N6796 when subjected to a total dose steady state irradiation up to
100KRad(Si) applied with a dose rate of 10.0 Rad(Si)/s. This component is a
Power MOS Field Effect Transistor, N Channel, in a TO-39 Metal Can Package.

Description (ctn):

The test method adopted was ESA/SCC 22900, Figure II. The dose rate employed was 10.0 Rad(Si)/s with electrical testing performed at 1, 2, 5, 10, 15, 25, 50 and 100kRad(Si). The sample size was 3 with one control sample.

Bias Condition and Circuit:

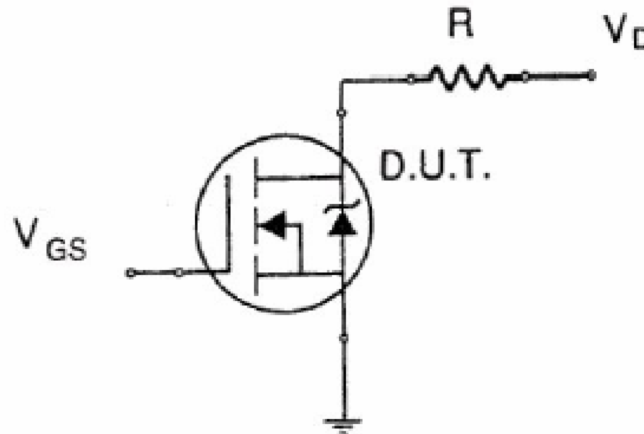
The bias condition used during irradiation test was:

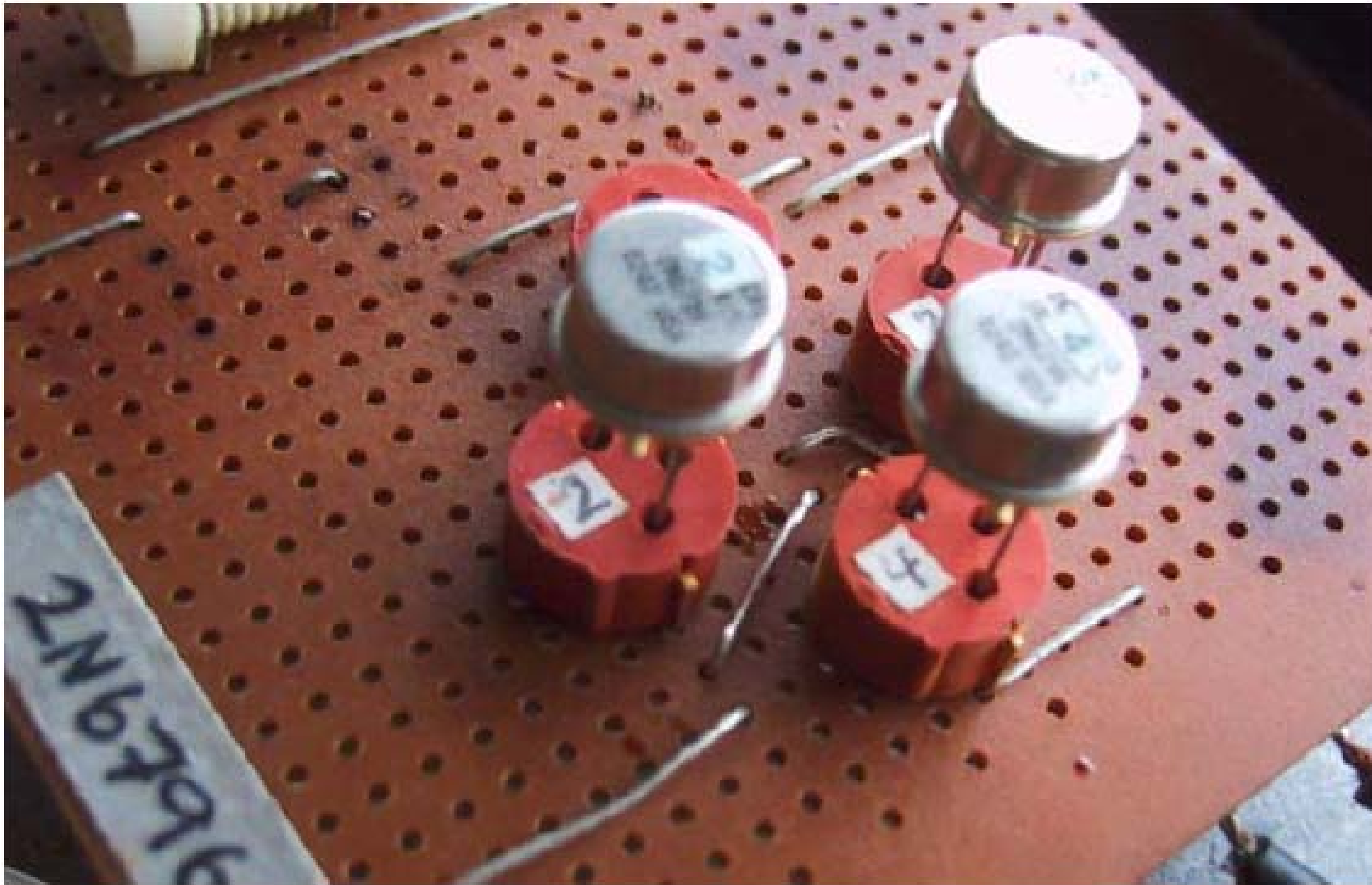
Drain-Source Voltage VDS = 30V

Gate-Source Voltage VGS = 10V

Resistor R = 300 10%

at Tamb = +25 ±5°C





Dispositivi sotto test

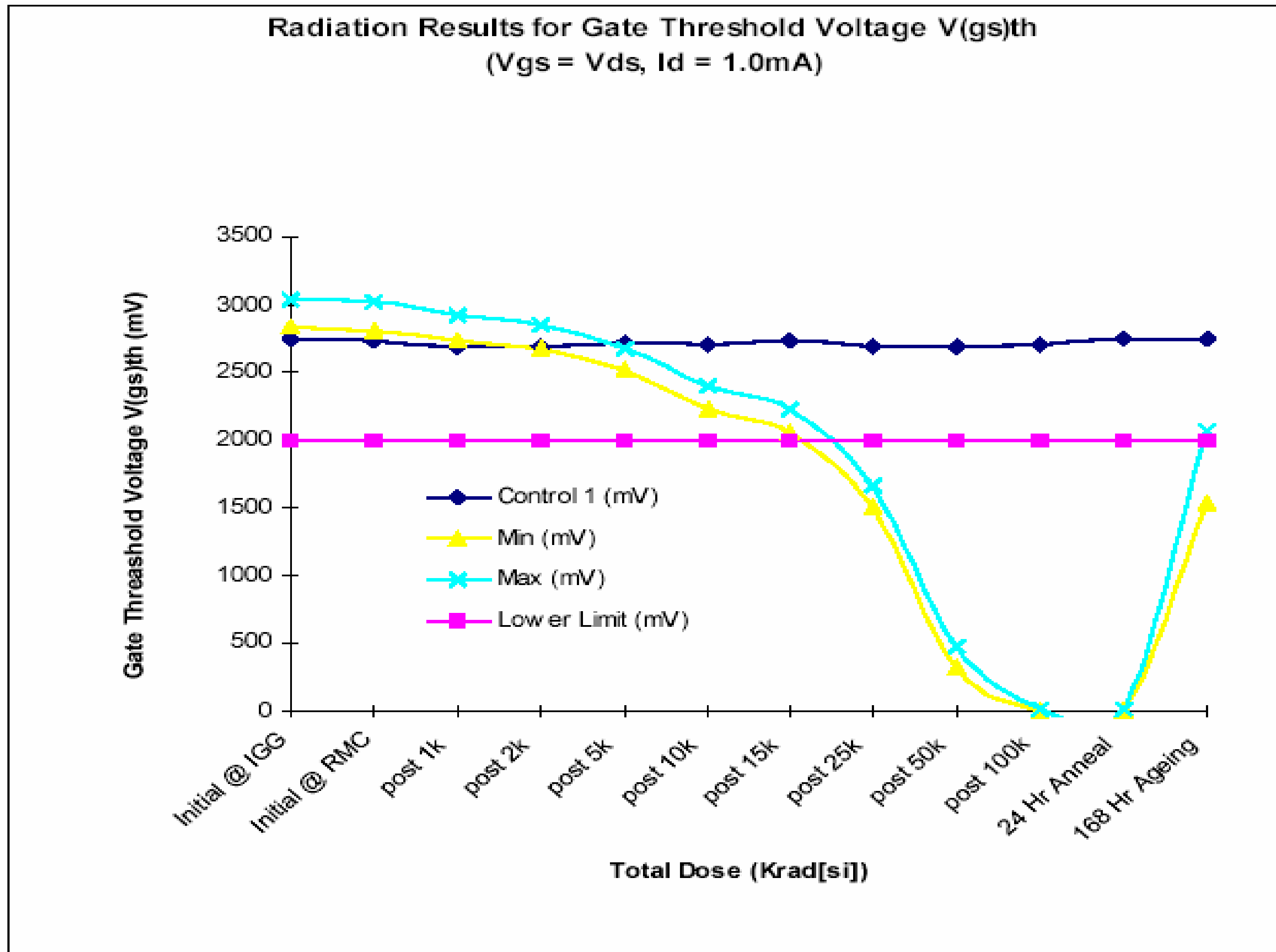
Irradiation Test Sequence		21
Test Step	**Description**	**Requirements**
1(a)	Serialisation Goods Receiving Inspection	If parts are not serialised, serialise them (permanently) sequentially from 1 to 4 inclusive. Goods Receiving Inspection shall consist of 100% Travel Visual, Visual Inspection and Electrical Measurements per Table A herein.
1(b)	Initial Electrical Measurements (at IGG)	Per Table A herein - Read & Record – 1 control + 3 parts minimum at IGG. (See remarks 1 and 3).
2	Initial Electrical Measurements (at RMC)	Per Table A herein - Read & Record – 1 control + 3 parts minimum at RMC. (See remarks 1 and 3).
3	Set-up of Test	Verify bias circuit and voltage (in-situ) for 1 control + 3 test samples.
4	Irradiation Exposure	Verify radiation dose rate and position in the chamber to achieve required dose. Verify and witness duration of exposure to achieve required dose.

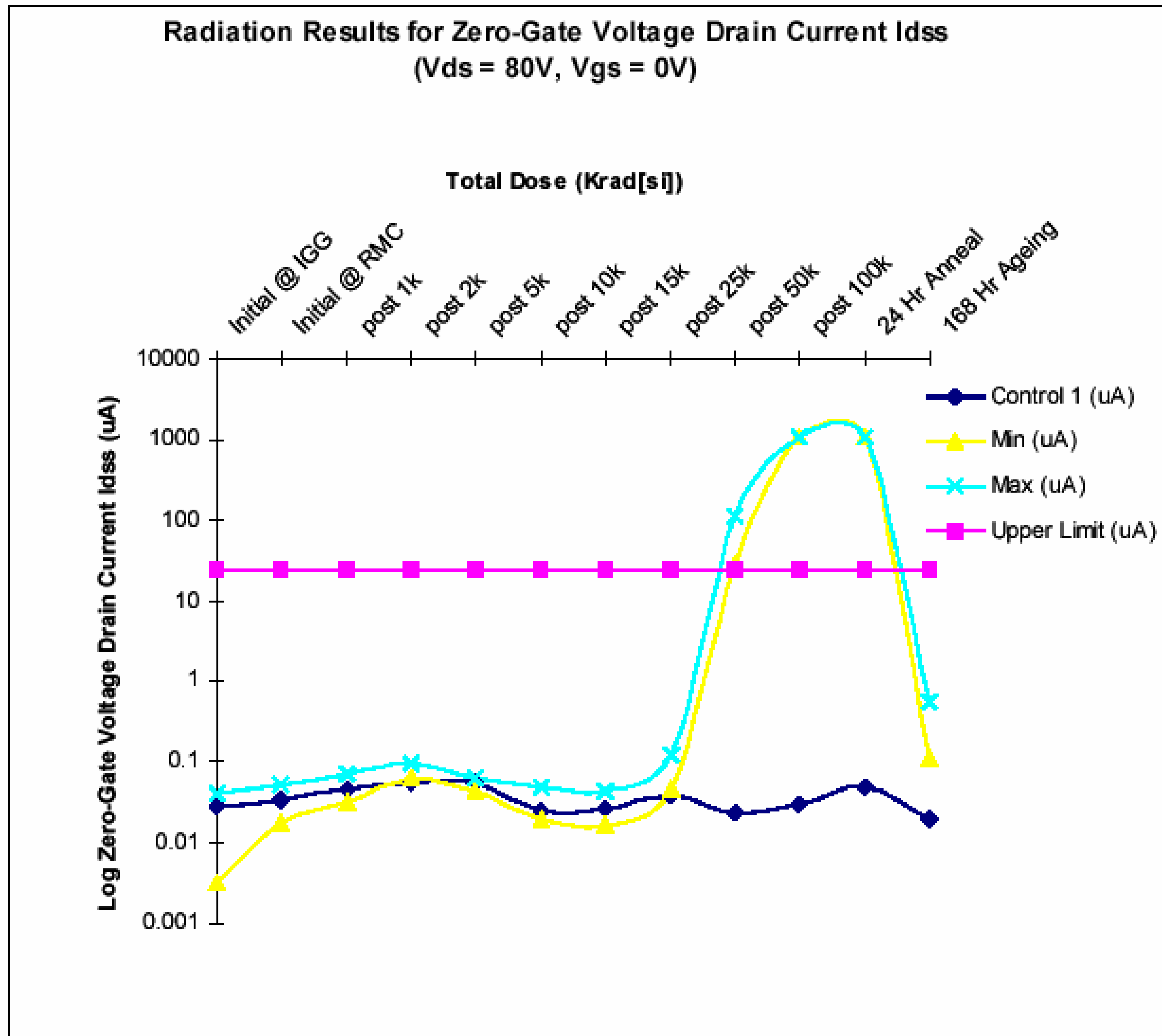
Test sequence (cnt.).

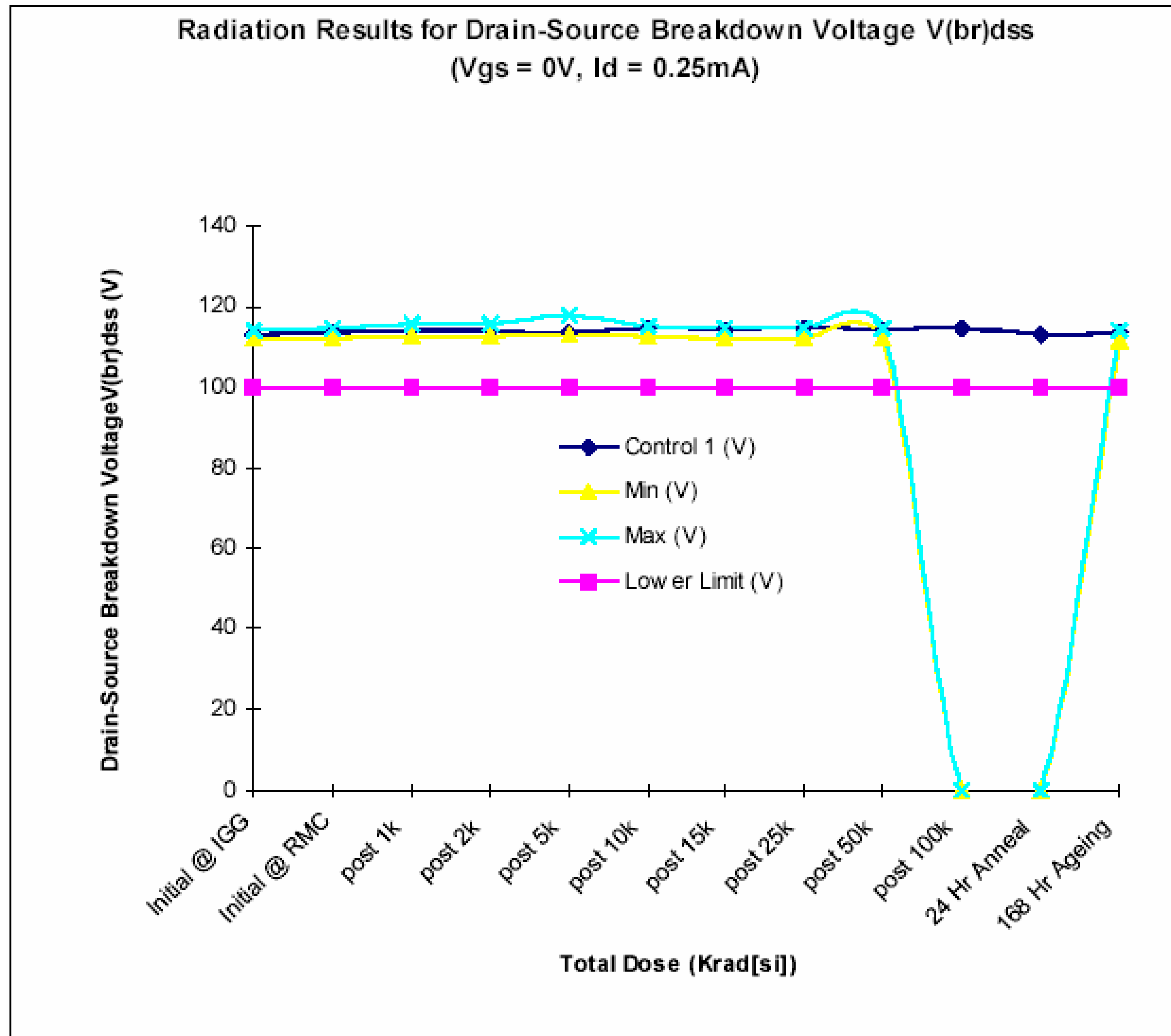
5	Intermediate Electrical Measurements	Bias to be maintained until test is performed. Test per Table A herein - Read & Record – 1 control + 3 parts. Test to be performed immediately upon removal from chamber (less than 10 mins interval). Upon completion of test devices to be replaced in bias circuit (1 control + 3 parts) and returned to chamber. Maximum interval between 2 consecutive exposures to be 30 mins.
6 to 26	Repeat Set-Up / Exposure / Test Sequence up to Total Dose of 100Krad(Si) as per plan above	Repeat Steps 3, 4 and 5 for a total of 6 cycles up to the total dose of 100kRAD(Si) at Dose 1, 2, 5, 10, 15, 25, 50 and 100kRAD (Si). The exact radiation exposure at each step shall be recorded.
27	Room Temperature Anneal Under Bias	24hrs (See Remark 4)
28	Post Room Temperature Anneal Electrical Measurements	Per Table A herein (Read & Record) on all 1 control + 3 parts at IGG. (See Remarks 3 and 5)
29	Accelerated Ageing Under Bias	168hrs at +100°C (See Remark 4)
15	Final Electrical Measurements	Per Table A herein - Read & Record – 1 control + 3 parts at IGG
16	Total Dose Irradiation Test Report	ESA/SCC No.: 22900

Remarks

1. Performed for the purposes of correlation.
2. The set-up / exposure / test sequence shall be stopped for any device that exhibits repeated functional failure.
3. All electrical testing shall be performed on the same test equipment in order to achieve correlation of results at IGG and RMC. All results plus details of any failures to be advised to project.
4. During annealing and Accelerated Ageing, bias per Figure 1 shall be applied.
5. End point electrical measurements (Test Step 12) shall be performed within 24 hours of the last electrical measurement at RMC


Radiation Results for Gate Threshold Voltage V(gs)th
(Vgs = Vds, Id = 1.0mA)
Gate Threshold Voltage V(gs)th (mV)
3500
3000
2500
2000
1500
1000
500
0
Control 1 (mV)
Min (mV)
Max (mV)
Lower Limit (mV)
Initial @ IGG
Initial @ RMC
post 1k
post 2k
post 5k
post 10k
post 15k
post 25k
post 50k
post 100k
24 Hr Anneal
168 Hr Ageing
Total Dose (Krad[si])


Radiation Results for Zero-Gate Voltage Drain Current Idss
(Vds = 80V, Vgs = 0V)
Total Dose (Krad[si])
Initial @ IGG
Initial @ RMC
post 1k
post 2k
post 5k
post 10k
post 15k
post 25k
post 50k
post 100k
24 Hr Anneal
168 Hr Ageing
Log Zero-Gate Voltage Drain Current Idss (uA)
10000
1000
100
10
1
0.1
0.01
0.001
Control 1 (uA)
Min (uA)
Max (uA)
Upper Limit (uA)


Radiation Results for Drain-Source Breakdown Voltage V(br)dss
(Vgs = 0V, Id = 0.25mA)
Drain-Source Breakdown VoltageV(br)dss (V)
140
120
100
80
60
40
20
0
Control 1 (V)
Min (V)
Max (V)
Low er Limit (V)
Initial @ IGG
Initial @ RMC
post 1k
post 2k
post 5k
post 10k
post 15k
post 25k
post 50k
post 100k
24 Hr Anneal
168 Hr Ageing
Total Dose (Krad[si])

The component stayed within specified limits for all specified electrical
parameters up to a dose of 15KRad(Si), applied as detailed per ESA/SCC22900.
This component appears to be fairly robust under the conditions it was tested
and can be considered hard, i.e. within all specified limits, to 15Krad when
tested under these conditions.

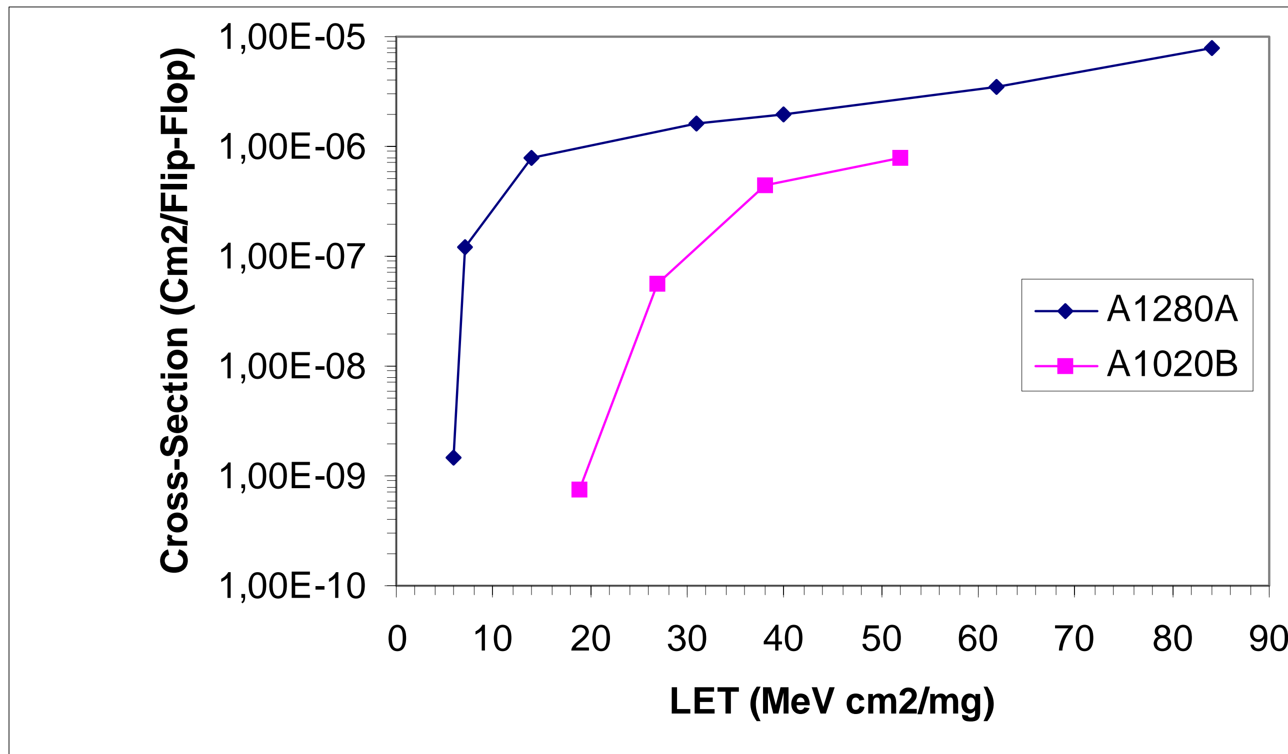
Calcolo del SEU rate in una missione

Caso: FPGA ACTEL A1280 e A1020 su l'orbita della ISS

Si parte dal calcolo del SEU rate associato al dispositivo:

Average SEU rate = 6.3 10^{-7}. error/day*bit

Diagramma della cross section per le due FPGA (data from NASA db)



Board name	Number/Type of ACTEL device	Number of Logic Cell used	Number of Total Logic Cell available	Number of Logic Cell considered for SEU calculation
Analog Input Board (AIB)	1/A1280A	172 [2)]	1232	250 (margin > 40%)
Power board #1 (PB1)	1/A1280A	900 [3)]	1232	1000 (margin > 10%)
Power Board #2 (PB2)	1/A1020	450 [4)]	547	500 (margin > 10%)
Power Board #3 (PB3)	2/A1020	450 [4)]	547	500 (margin > 10%)

Notes:
1) Data coming from Actel Designer Lite performed on the FM FPGA design, all the functionality indicated in RD3 section 3.1.2 included with the only exception of the Watch Dog Timer.
2) Data coming from Actel Designer Lite performed on the FM FPGA design
3) Data coming from Actel Designer Lite
4) Data based on the XXX project,

Calcolo del SEU rate

Device/Board name	Seu Rate (error/day*bit or day*Logic cell)	Number of Logic Cell	Mission Time (years)	Duty cycle (see RD4)	SEU events,errors /mission
A1280A/AIB	6.3E-7	250	3years	1	0.17 events
A1280A/PB1	6.3E-7	1000	3years	1	0.69 events
A1020/PB2 *	6.3E-7	500	3years	1	0.35 events
A1020/PB3 *	6.3E-7	500	3years	1	0.35 events

Notes:
* Worst case estimation

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For the calculation of the total number of events during the mission it has to consider all the FPGAs used in the mission, therefore the following avionics configuration shall be considered:
N. 1 PB1 Board
N. 1 PB2 Board
N. 1 AIB Board
N.2 PB3 boards

Starting from the the total number of events in the mission is:

1,91 events

Effetti del SEU sul sistema

E' importante valutare gli effetti del SEU sul sistema.

Capire se il sistema si porta in stati di non ritorno o eseguire operazioni fuori controllo.

Fare un'analisi di FMECA sui componenti coinvolti nel SEU e capire gli effetti sul sistema

Part	Type	SEU LET th/Cross sec.	SEU effects
AD574AUD	A/D 12bits		S/W filtering action on telemetry data reading. Non consequences on the system
54HC74 Dual D FF			In the worst case erroneous switch-off of an outlet. In any case this device would not be sensitive to SEU in fact the 54HC374 (octal D-F/F) has a SEU LETth > 75MeVcm2/mg (JPL data ase)
54ABT16373W-QML	Latch 16x	> 100 for parts in the same family (JPL data base)	S/W filtering action on telemetry data reading. Non consequences on the system. Erroneous power on/off of the thermistors current supply . No temperature reading until the current supply is switched on.
A1280A-1 CQ172B	FPGA		Temporary (1 telemetry reading cycle) Error in status bit monitoring of power boards. Erroneous activation/Deactivation of Power Boards functions
A1020B-CQ84B	FPGA		Temporary (1 telemetry reading cycle) Error in status bit monitoring of power boards . Erroneous activation/Deactivation of Power Boards functions
AD822SQ /883B	OP-AMP		Filtered by downstream circuit