Recent Radiation Test Results at JPL

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ABSTRACT

This paper documents recent TID test results (including proton damage and ELDRS) obtained by JPL. Unusual test results, such as abnormally low or high failure levels or unusual failure or response mechanisms, are emphasized.

[NOTE: In this paper summary, only a partial set of parts are listed and discussed. The final paper will list all parts tested for TID or proton damage over the past three years (approximately 50), except for proprietary tests.]

INTRODUCTION

This paper documents selected, recent TID radiation test results (including proton damage and ELDRS testing) obtained by the NASA Jet Propulsion Laboratory (JPL). This paper is not a full compendium, as it only covers the past three years of testing. Also, the emphasis in this paper is on unusual test results, such as exceptionally low or high TID failure levels or unusual failure or response mechanisms.

DISCUSSION

A significant number of semiconductor, photonic, and MEMS devices have been tested at JPL over the past few years. Table 1 provides a tabular summary of the parts tested, the conditions of the test, and the principal results. Parts are listed by manufacturer number (with any military prefixes omitted; see reports for more details). Note that the table only provides average (mean) dose or fluence levels, not "worst-case" values. Definitions of "worst case" vary, but the one normally preferred is 99/90, which is defined as 90% confidence (based on the sample size tested) that the survival probability of the lot is ≥99% at the specified dose or fluence. (Of course, for most parts, the term "lot" does not refer to wafer lot, but merely date code.) Individual test reports and data must be examined to determine "worst-case." Unless otherwise noted, TID testing was performed at JPL's High- or Low-Dose Rate Cobalt-60 gamma ray facilities, and proton testing was performed at UC Davis. In the following sections, a number of parts tested are briefly discussed. Additional data may be obtained through JPL's RadNet website [1] or by contacting the author(s).

1N5665A Zener Diode (Microsemi). This JANTX1N5665A is a 200-V transient absorption zener diode. It was tested unbiased with 63-MeV protons at UC Davis to a fluence of 1.19×10^{11} p/cm^2 (corresponding to a dose of 16 krads). The purpose was to determine whether displacement damage would cause significant changes would occur in breakdown voltage, leakage current, or dynamic impedance in such a high-voltage device. All changes were very minor. The largest percentage change was a 3% reduction in breakdown voltage. Leakage current remained within specifications, typically only rising ~10 n

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2N2222A NPN Transistor (Semicoa). These parts were provided in chip form (no diffusion lot information) and packaged at JPL. They were tested with V_{CB} = 50 V. They performed within specification up to 30 krads, with low-current h_{FE} falling below specification at 60 krads. High-current h_{FE} remained within specification up to 300 krads. I_{CBO} and $V_{CE(sat)}$ did not change significantly up to up to the highest test level of 300 krads.

2N2484 NPN Transistor (Motorola). This JANS2N2484 NPN transistor was tested with V_{CB} = 48 V. They performed within specification up to 100 krads. I_{CBO} increased by 90 pA at 200 krads and $V_{CE(sat)}$ only increased by 10 mV at 200 krads.

2N2907A PNP Transistor (Semicoa). These parts were provided in chip form (no diffusion lot information) and packaged at JPL. They were tested with V_{CB} = -50 V. They performed within specification up to 60 krads, with low-current h_{FE} falling below specification above 60 krads. High-current h_{FE} remained within specification up to 300 krads. I_{CBO} and $V_{CE(sat)}$ exceeded specification values at 300 krads.

4N49 Optocoupler (Micropac). This JANTX4N49 optocoupler was tested unbiased with 50-MeV protons at UC Davis. Two date code lots were irradiated up to a fluence of 3.4×10^{10} p/cm^2. The current-transfer ratio (CTR) of the more sensitive lot dropped below the required value of 0.47 at a worst-case fluence of 2.3×10^{10} p/cm^2.

AD590 Temperature Transducer (Analog Devices). This bipolar IC was tested by both Raytheon and JPL in separate tests. It is susceptible to ELDRS, and fails at an average dose of 25-30 krads during unbiased irradiation and 70 krads when biased. (While failure doses were higher at high dose rates, they are not valid for space applications.)

AD768 D/A Converter (Analog Devices). This 16-bit DAC is a BiCMOS part. It was tested biased at high dose rate and performed within specifications up to 50 krads. Between 50 and 100 krads, Vref and integral nonlinearity (INL) were out of specification. However, the part continued to function with somewhat degraded parameters up to 200 krads. (It is not known whether this part is susceptible to ELDRS.)

ADC1175 A/D Converter (National). This 8-bit A/D converter (CMOS) was tested biased at high dose rate and performed well up to 50 krads, after which, it went out of specification, although it continued to function with degraded parameters up to 175 krads.

IRFMG40 Power MOSFET (International Rectifier). This is a 1000-V, N-channel MOSFET. For an unhardened device, its total dose capability was respectable. Tests were performed at high, low, and room temperatures, with parts exposed in two bias modes: (1) gate at 5 V with drain at 0 V; or (2) gate at 0 V with drain at 800 V. (Extended temperature testing was only performed pre-rad and after 16 krads to minimize annealing.) Principal changes observed were for gate-threshold voltage, drain-source breakdown voltage, and drain-source leakage current. The most marginal parameter was breakdown voltage at –55°C, which just barely exceeded the 1000-V specification pre-rad. This declined to ~930 V after 16 krads, but this should not be a problem for a properly derated part. Other parameters remained within specification or usable ranges throughout the testing up to the maximum of 16 krads.

LF2802A RF Power MOSFET (M/A-Com). This is an RF, N-channel, DMOS FET. It was tested in various bias modes: unbiased, gate biased, and drain-to-source biased. The unbiased and drain-to-source biased parts remained in specification up to 25 krads, but the gate-biased parts went out of specification for gate threshold voltage after 5 krads. Changes in gate or drain-to-source leakage currents were very minor up through 50 krads.

LM124A Op Amp (National). This bipolar IC is a quad, low-power, op amp that was built at National's Grenock, Scotland facility. It was tested at various bias modes and dose rates to characterize ELDRS behavior. As shown in Fig. 1, both the biased and unbiased parts went out of specification for bias current (50 nA) at approximately 3-4 krads at low dose rate. At high dose rates, both the biased and unbiased parts went out of specification for offset voltage (2 mV) at approximately 5 krads. However, with appro-

priate parametric derating, these parts can be used at levels up to 30 krads.

MAX306 Multiplexer (Maxim). This 16-channel multiplexer (CMOS) was initially tested biased at high dose rate with address pins high. However, all three parts failed functionally at the first step of 1 krad. A second test was then performed at low dose rate and with address pins rolling dynamically (corresponding to application usage). As shown in Fig. 2, degradation started at 1.5 krads with $I_{D(on)}$ exceeding the 20-nA specification. It reached 300 nA at 3 krads, but the part continued to function up to 5 krads with $I_{D(on)}$ increasing to a microampere.

MAX539 D/A Converter (Maxim). This 12-bit DAC is a CMOS part. It was tested biased at high dose rate, and while minor parametric degradations were noted, the devices performed within specifications up to 10 krads. Between 10 and 20 krads, severe degradations occurred for many parameters, such as linearity and supply currents.

SUMMARY

This paper provides a compendium of parts tested for total ionizing dose and proton damage at JPL over the past few years. These data are only intended to be used as a guide for consideration in space applications with various radiation requirements. Since only average data is discussed in this summary, individual test reports should be reviewed for more detail. Also, since modern parts tend to evolve, "improve," or otherwise change processes frequently, radiation lot acceptance testing is recommended.

REFERENCES

[1] JPL RadData website – http://radnet.jpl.nasa.gov/

Table I. Summary of Recent TID/DD Test Results at NASA Jet Propulsion Laboratory

Part Type	Description	Tech.	Mfr.*	Date Code	Sample Size	Dose Rate (rad/s)	Bias During Exposure	Failure Parameter	Spec. Limit	Pre-Rad Value	Av. Dose/ Fluence to Parm. Failure	Av. Dose/ Fluence to Func. Failure	Comments
1N5665A	Zener Diode	Diode	Microsemi	0039A	5	Protons	Unbiased	BV, I_L			>1.2E11		Very minor changes
2N2222A	NPN Transistor	Si, NPN	Semicoa	Chip	6	50 (HDR)	Biased	h_{FE} @ 0.1mA			60 krads	300 krads	Usable with derating >60K
2N2484	NPN Transistor	Si, NPN	Motorola	9201	3	~50 (HDR)	Biased	h_{FE}			>100 krads	>200 krads	Good to 100 krads
2N2907A	PNP Transistor	Si, PNP	Semicoa	Chip	6	50 (HDR)	Biased	h_{FE} @ 0.1mA			60 krads	300 krads	Usable with derating @ 100K
4N49	Optocoupler	LED, pho-totransistor	Micropac	9810, 9838	5	Protons	Unbiased	CTR			2.5E10		
AD590FK/883B	Temp. Transducer	Bipolar IC	An. Dev.	9731K	5	100 (HDR)	Biased	T	5°C		200 krads		
AD590FK/883B	Temp. Transducer	Bipolar IC	An. Dev.	9731K	5	100 (HDR)	Unbiased	T	5°C		100 krads		
AD590FK/883B	Temp. Transducer	Bipolar IC	An. Dev.	9731K	5	0.05 (LDR)	Biased	T	5°C		70 krads		Dose rate not low enough
AD590FK/883B	Temp. Transducer	Bipolar IC	An. Dev.	9731K	5	0.05 (LDR)	Unbiased	T	5°C		25 krads		Dose rate not low enough
AD590FK/883B	Temp. Transducer	Bipolar IC	An. Dev.	9731K	5	0.01 (LDR)	Unbiased	T	5°C		30 krads		
AD590JH/883B	Temp. Transducer	Bipolar IC	An. Dev.	9122B	3	50 (HDR)	Biased	T	5°C		350 krads		
AD590JH/883B	Temp. Transducer	Bipolar	An. Dev.	9122B	4	0.02 (LDR)	Biased	T	5°C		100 krads		Dose rate not low enough
AD768AR	D/A Conv., 16-bit	BiCMOS	An. Dev.	9805, 9746	4	25 (HDR)	Biased	Vref,			50-100 krads	300-500 krads	BiCMOS part; not tested for ELDRS nor unbiased
ADC1175	A/D Converter	CMOS	National	--	4	50 (HDR)	Biased	IAdd, IDdd			50 krads	>175 krads	
ADG411	Switch, quad	LC²MOS	An. Dev.										
AMA2805D	DC/DC converter	Hybrid	Advanced Analog	127	1	25 (HDR)	Biased	Functional				33 krads	
AMA2805D	DC/DC converter	Hybrid	Advanced Analog	127	1	0.05 (LDR)	Biased	Functional				44 krads	
AMF2805D	DC/DC converter	Hybrid	Advanced Analog	124	1	25 (HDR)	Biased	Functional				40 krads	
AMF2805D	DC/DC converter	Hybrid	Advanced Analog	124	1	0.05 (LDR)	Biased	Functional				47 krads	
ARH2803.3S	DC/DC converter	Hybrid	Advanced Analog	129	2	25 (HDR)	Biased	Functional				>300 krads	
ARH2805S	DC/DC converter	Hybrid	Advanced Analog	129	3	25 (HDR)	Biased	Functional				>300 krads	
DG406	Multiplexer, 16-ch	CMOS	Maxim	9918	3	? (HDR)	Biased, static	Functional	--	--	--	<5 krads	

Part Type	Description	Tech.	Mfr.*	Date Code	Sample Size	Dose Rate (rad/s)	Bias During Exposure	Failure Parameter	Spec. Limit	Pre-Rad Value	Av. Dose/ Fluence to Parm. Failure	Av. Dose/ Fluence to Func. Failure	Comments
IRFMG40	MOSFET, 1000V	N-channel	Int. Rect.	0032	8	25 (HDR)	Gate or drain biased	BVds, I_{DSS}, $V_{G(th)}$	various		~14 krads	>16 krads	Usable to ~16 krads with some parameter derating @ high/low temperatures
LF2802A	MOSFET, RF	N-channel	M/A-Com	01F15	6	50 (HDR)	Various biases	$V_{G(th)}$	various		5 krads	5-10 krads	Usable to >5 krads with $V_{G(th)}$ derating
LM124A	Op amp, quad	Bipolar	National	HOD0110B	3	50 (HDR)	Biased	V_{OS}	2 mV		5 krads	>30 krads	Scotland foundry
LM124A	Op amp, quad	Bipolar	National	HOD0110B	3	50 (HDR)	Unbiased	V_{OS}	2 mV		5 krads	>30 krads	Scotland foundry
LM124A	Op amp, quad	Bipolar	National	HOD0110B	3	0.01 (LDR)	Biased	I_{B+}	50 nA		3-4 krads	>30 krads	Scotland foundry
LM124A	Op amp, quad	Bipolar	National	HOD0110B	3	0.01 (LDR)	Unbiased	I_{B+}	50 nA		3-4 krads	>30 krads	Scotland foundry
LTC1157CS8	MOSFET driver	CMOS	Lin. Tech.	819	5	25 (HDR)	Biased	Voh, Iccl	--	--	3 krads		OK to 2.5 krads
MAX306EWI	Multiplexer, 16-ch	CMOS	Maxim	0143	3	25 (HDR)	Biased	Functional	--	--	--	<1 krad	Address lines high
MAX306EWI	Multiplexer, 16-ch	CMOS	Maxim	0143	4	0.01 (LDR)	Biased	ID(on)	300 nA	20 nA	3 krads	5 krads	Address lines rolling dynamically
MAX539	D/A Conv., 12-bit	CMOS	Maxim	GF008	4	25 (HDR)	Biased, clocked	Linearity			>10 krads	<20 krads	Minor parametric changes within spec. at 10 krads

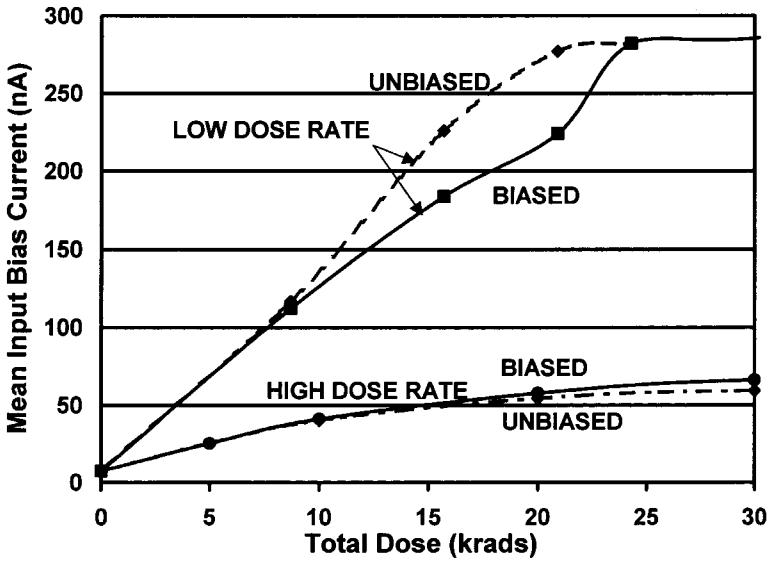

Fig. 1. Mean Input Bias Current for National LM124A Op Amp

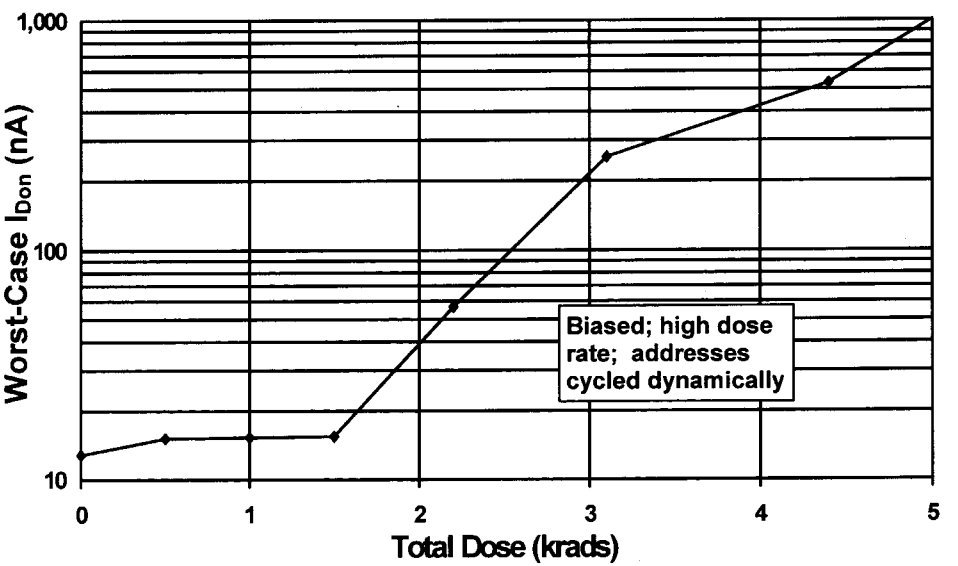

Fig. 2. I_{Don} Leakage Current for Maxim MAX306 Multiplexer