NASA Goddard Space Flight Center's Recent Radiation Effects Test Results

National Aeronautics and Space Administration

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Abstract: Total ionizing dose, displacement damage dose, and single event effects testing were performed to characterize and determine the suitability of candidate electronics for NASA space utilization. Devices tested include FPGAs, optoelectronics, digital, analog, and bipolar devices.

Introduction

NASA spacecraft are subjected to a harsh space environment that includes exposure to various types of radiation. The performance of electronic devices in a space radiation environment is often limited by its susceptibility to single-event effects (SEE), total ionizing dose (TID), and displacement damage dose (DDD). Ground-based testing is used to evaluate candidate spacecraft electronics to determine risk to spaceflight applications. Interpreting the results of radiation testing of complex devices is quite difficult. Given the rapidly changing nature of technology, radiation test data are most often application-specific and adequate understanding of the test conditions is critical.

These test results show sensitivities of candidate spacecraft and electronic devices to SEE including single-event upset (SEU), single-event functional interrupt (SEFI), single-event latchup (SEL), single-event transient (SET), TID, and DDD effects. All tests were performed between March 2021 and February 2022.

Summary

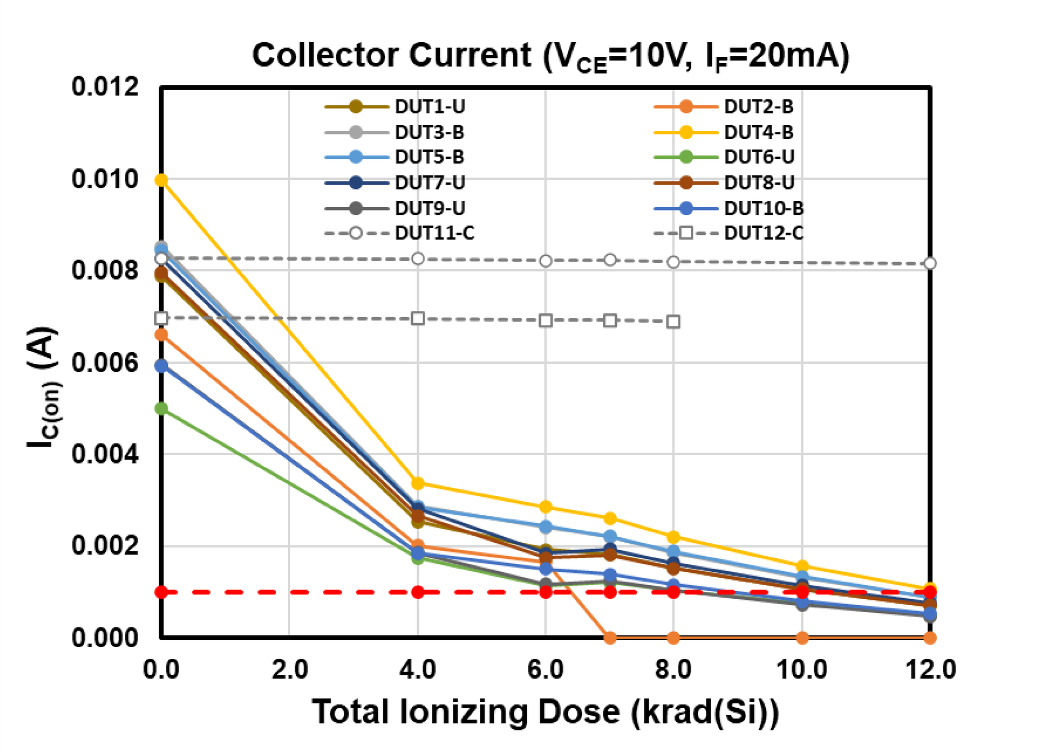
We have presented data from recent radiation tests on a variety of devices including several commercial parts. It is the authors' recommendation that this data be used cautiously as many tests were conducted under application- or lot-specific test conditions. We also highly recommend that lot-specific testing be performed on any suspect or commercial device.

See full paper for:

- Test Techniques and Setup
- Principal Investigators,
- Abbreviations and Conventions
- Acknowledgments
- References

TT Electronics OMT1090

The optical switches showed variability before irradiation, variability was exacerbated by total dose effects. Test results show radiation negatively impacts the phototransistor more than the photodiode.



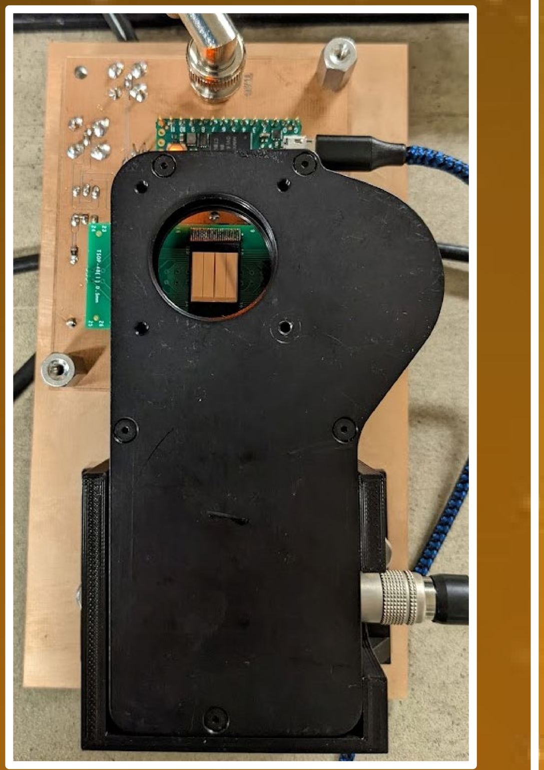
On-state Collector Current (A) vs. Dose (krad(Si)) for each DUT.

The OMT1090 is a 50V slotted optical switch with a gallium aluminum arsenide LED and a silicon phototransistor tested at Crocker Nuclear Laboratory, University of California at Davis

Micron MT29F16G08ABABAWP Flash Memory

A 16 Gb commercial NAND flash device was tested for single-event effects as part of a flight project anomaly investigation to evaluate any impacts to device reliability after repeated power cycles to mitigate single-event functional interrupts (SEFI).

A fast optical shutter was activated as part of an autonomous SEFI test controlled by an ARM Cortex-M4 microcontroller visible at the top edge of the figure to the right.



Thorlabs SH1 shutter was mounted above the DUT

Summary of Radiation Test Results

Part Number	Manufacturer	LDC; (REAG ID#)	Device Function	Technology	PI	Sample Size	Test Environment	Test Facility (Test Date)	Test Results (Effect, Dose Level/Energy, Results)
66212-301	Micropac	2051; (19-047)	Optocoupler	Hybrid	TW	12	Protons	UCD (Oct 2021)	DDD and TID, No failures up to 2.2 x 10^{11} protons/cm^2 or TID equivalent 29.3 krad(Si).
FBG20N18	EPC Space	Y003; (21-018)	HEMT	GaN	JML	7	Heavy Ions	LBNL (Jun 2021)	No SEB with 10 MeV/n Xe (LET = 59 MeV-cm^2/mg(Si)) at V_{GS} = -4V & V_{DS} = 200V 185 V_{DS} < SEB threshold < 190 V_{DS} at -4 V_{GS} with 10 MeV/n Au (LET = 86 MeV-cm^2/mg(Si)).
FBG30N04	EPC Space	T047; (21-019)	HEMT	GaN	JML	5	Heavy Ions	LBNL (Jun 2021)	No SEB at 300 V_{DS} & -4 V_{GS} with 10 MeV/n Au (LET=86 MeV-cm^2/mg(Si)). I_D degradation onset ~250 V_{DS} but I_{DSS} remained in manufacturer spec after 10^7 cm^{-2} Au ions.
JANS2N2907AUB	Semicoa	2026; (21-005), 2012A; (21-006), 2028; (21-007), 1921; (21-008)	Transistor	Bipolar	TW	88	Gamma	GSFC (Jun 2021)	TID, LDR, No parametric failures noted below 30 krad(Si).
JANS2N5339	Semicoa	1747; (21-010)	Transistor	Bipolar	TW	10	Gamma	GSFC (Sep 2021)	TID, LDR, No functional failures to 36 krad(Si).
JANSR2N7593	Microchip	C2052; (21-020)	MOSFET	Si	JML	3	Heavy Ions	LBNL (Jun 2021)	No SEB/SEGR up to 10 MeV/n Au (LET = 86 MeV-cm^2/mg) at V_{DS} = 250V & V_{GS} = 0V; No SEB/SEGR with 10 MeV/n Ag (LET = 48 MeV-cm^2/mg) at V_{DS} = 250V & V_{GS} = -20V.
LIFCL-40-8BG400CE82 (CrossLink)	Lattice Semiconductor	2048; (21-016)	FPGA	40nm CMOS	MB	2	Gamma	GSFC (Mar 2021)	TID, HDR, 330 krad(Si), A "first look" test, New dial-down approach was used to measure internal delay paths. DUT4 saw input-rise to output-rise delay measurements increase by 6ns over dose. The voltage regulator died after 275 krad(Si). DUT5 saw input-rise and output-rise delay measurements increase by 6ns over dose. The voltage regulator died at 330 krad(Si). Further studies are in progress.
LT3482	Analog Devices	n/a; (21-024)	DC/DC Converter	Bipolar	JB	2	Gamma	GSFC (Jul 2021)	TID, HDR (No ELDRS consideration), 100 krad(Si), Output voltage showed < 0.5% decrease from pre-irradiation values at 100 krad(Si).
LTC1604	Linear Technology	1537; (21-025)	ADC	CMOS	MBJ	3	Heavy Ions	LBNL (Sep 2021)	SEL: 49 < LET_{th} < 53 and 40 deg C. SEL saturated CS: ~1x10^{-6} cm^2.
LTC2054	Linear Technology	2034; (21-022)	Op Amp	Bipolar	MBJ	10	Gamma	GSFC (Jul 2021)	TID, LDR, 100 krad(Si), All device parameters stayed in specification up to a dose level of 80 krad(Si). Degradation in biased devices were observed in input offset voltage variance, high voltage swing, quiescent current, and slew rate variance. Biased input offset voltage lower bound went out of datasheet specification between 80 krad(Si) and 90 krad(Si). Biased quiescent current upper bound went out of datasheet specification between 90 krad(Si) and 100 krad(Si). Degradation in unbiased (grounded) devices was observed in high voltage swing measurement. Grounded device parameters remained in datasheet specifications up to 100 krad(Si).
MSK130	M. S. Kennedy/TTM Technologies	n/a; (21-024)	Differential Amplifier	BiCMOS	JB	2	Gamma	GSFC (Jul 2021)	TID, HDR (No ELDRS consideration), Current draw had increased by an order of magnitude and the part was not functional at 10 krad(Si).
MT29F16G08ABABAWP	Micron	1642; (22-003)	Flash	CMOS	TW	6	Heavy Ions	LBNL (Feb 2022)	See Section IV, B for the full results.
OMT1090	TT Electronics	M2047; (21-012)	Opto-electronics	Hybrid	TAC	10	Protons	UCD (Oct 2021)	DDD, 64 MeV, No effects were seen up to 4 krad(Si) or 3.01x10^{10}, $V_{BR(CEO)}$ went out of specification at 6 krad(Si) or 4.52 x 10^{10} protons/cm^2 for biased DUTs, DUT 2 failed at 6 krad(Si). Collector current went below specification after 7 krad(Si).
PIC18F4685T	Microchip	n/a; (21-032)	Microcontroller	CMOS	TW	5	Heavy Ions	LBNL (Jun 2021)	SEL was observed; no parts damaged in testing SEL LET_{th} < 2.4 MeVcm^2/mg (1.25x10^{-6} cm^2) CS SAT: 2.68x10^{-3} cm^2 @ LET 25 MeVcm^2/mg, 3 parts irradiated with LET 76.7 MeVcm^2/mg at 85°C to at least 1x10^7/cm^2 with no permanent failures.
RM3100	PNI	n/a; (21-017)	Sensor	CMOS	TW	2	Heavy Ions	LBNL (May 2021)	SEL, LET_{th} > 76 MeVcm^2/mg at 3.3 V and 85 deg C, 3.7 < SEFI LET_{th} < 7.3 MeVcm^2/mg, SEFI saturated CS ~1x10^{-5} cm^2.
Si5345	Silicon Labs/Sky Works	n/a; (21-024)	Clock Synthesizer	CMOS	JB	2	Gamma	GSFC (Jul 2021)	TID, HDR, 100 krad(Si), Less than 1% decrease of output voltage over dose.
SY88422L	Microchip	n/a; (21-024)	Laser Driver	SiGe	JB	2	Gamma	GSFC (Jul 2021)	TID, HDR, 100 krad(Si), No radiation induced degradation of timing performance for 10 ns input pulses during testing was observed.
Edge TPU Accelerator Module	Coral	n/a; (22-001)	Tensor Processing Unit	CMOS	MCC	12	Gamma	GSFC (Dec 2021)	TID, HDR, 30 krad(Si), biased DUTs were unable to connect via USB. PGOOD was checked and voltage was nominal indicating the on-board voltage regulator is functioning normally. Grounded DUTs survived to 75 krad(Si).
Neural Compute Stick 2	Intel	n/a; (22-002)	Vision Processing Unit	CMOS	MCC	12	Gamma	GSFC (Dec 2021)	TID, HDR, 20 krad(Si) HDR, 3 of the 6 grounded DUTs were unable to connect via USB. All 6 biased DUTs were unable to connect via USB at 25 krad(Si). Remaining 3 unbiased DUTs were also unable to connect at 30 krad(Si).