

Screening Parts for Space Missions Using a Pulsed Laser to Test for Failures

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Acronyms

Abbreviation	Definition
ASIC	Application Specific Integrated Circuit
DDC	Data Device Corporation
DDD	Displacement Damage Dose
ESA	European Space Agency
FET	Field Effect Transistor
GSFC	Goddard Space Flight Center
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
LET	Linear Energy Transfer
MAPLD	Military and Aerospace Programmable Logic Devices
NASA	National Aeronautics and Space Administration
NRL	Naval Research Laboratory
RADECS	Radiations Effects on Components and Systems
RDC	Resolver-to-Digital Converter
SEB	Single-Event Burnout
SEE	Single-Event Effect
SEFI	Single-Event Functional Interrupt
SEGR	Single-Event Gate Rupture
SEL	Single-Event Latchup
SET	Single-Event Transient
SEU	Single-Event Upset
SSPC	Solid-State Power Converter
TAMU	Texas A&M University
TID	Total Ionizing Dose

Parts Screening

In a radiation environment, an IC's performance degrades gradually via:

- Total Ionizing Dose (TID)
- Displacement Damage Dose (DDD)

And “instantaneously” via:

- Single Event Effects (SEEs)

Parts Screening - TID

Radiation-effects engineers follow these steps when screening a part:

- First determine whether the TID level of an IC meets mission requirements:
 - Defense Logistics Agency **5962_XXXXXX** $L=(50 \text{ krad(Si)}, R=100 \text{ krad(Si)})$
 - Manufacturer's data sheet
 - Data bases: IEEE Data Workshop, RADECS data workshop, NASA, ESA, etc.
- Then, in the absence of data, do TID testing which involves:
 - Procuring 12 parts for statistics – time and expense
 - Exposing parts to gamma rays in a ^{60}Co source – remote or own ^{60}Co cell
 - Performing testing at high (50 – 300 rad(Si)/s) or low dose rates (0.01 rad(Si)/s)

Parts Screening - SEE


If the IC passes TID specifications, next step is to evaluate IC for SEEs:

- Defense Logistics Agency
- Manufacturer's data sheet
- Data bases: IEEE Data Workshop, RADECS data workshop, NASA, ESA, etc.

Revision

LTN	DESCRIPTION	DATE (YR MO DN)	APPROVED
A	Issue drawings to 1.0 and generation of master (see APPROVED A - 1)	06-09-03	Raymond Moton
B	Add device type 05. Update parameters to 2.0. 1% dose 1 figure 1. 2. 3 dose APPROVED A - 1	06-09-03	Raymond Moton
C	Update drawing to correct requirements. Electrical change through 1.0	09-09-04	Raymond Moton
D	Add device type 02 and 04. Change figure 4 diagram to show circuit reference to device data 30 requirements	10-09-05	Charles P. Sully
E	Add device type 03. Issue figures 7 and 2. Single event phenomena (SEP) and SET	11-09-05	Charles P. Sully

Image Credit: DLA.mil



REV	DATE	BY	CHKD	APPD	DESCRIPTION
01	06-09-03	RM	CS	RM	Issue drawings to 1.0 and generation of master (see APPROVED A - 1)
02	06-09-03	RM	CS	RM	Add device type 05. Update parameters to 2.0. 1% dose 1 figure 1. 2. 3 dose APPROVED A - 1
03	09-09-04	RM	CS	RM	Update drawing to correct requirements. Electrical change through 1.0
04	10-09-05	RM	CS	RM	Add device type 02 and 04. Change figure 4 diagram to show circuit reference to device data 30 requirements
05	11-09-05	RM	CS	RM	Add device type 03. Issue figures 7 and 2. Single event phenomena (SEP) and SET

STANDARD MICROCIRCUIT DRAWING

THIS DRAWING IS AVAILABLE FOR USE BY ALL DEPARTMENTS AND AGENCIES OF THE DEPARTMENT OF DEFENSE

DESIGNED BY: Raymond Moton
 CHECKED BY: Robert Whitcomb
 APPROVED BY: Raymond Moton
 DRAWING APPROVAL DATE: 06-09-03

DLA LAND AND NAVYTIME
 COLUMBUS, OHIO 43218-3399
<http://www.landandnavytime.dla.mil>

MICROCIRCUIT, DIGITAL-LINEAR, RADIATION HARDENED DUAL INVERTING MOSFET DRIVER, MONOLITHIC SILICON

REVISION LEVEL: 0
 DATE CODE: 0308
 SIZE: 8992-99911
 SHEET: 1 OF 24

Image Credit: DLA.mil

1.3 Absolute maximum ratings

Thermal resistance, junction-to-case (R_{θJC}):
 Case 1 87°C/W
 Case 2 100°C/W
 Thermal resistance, junction-to-board (R_{θJB}):
 Case 1 90°C/W
 Case 2 117°C/W

1.4 Recommended operating conditions

Supply voltage range (V_{CC}):
 Device type 01, 02, 03, 04 5.0 V to 10 V
 4.5 V to 10 V
 Line voltage locked voltage:
 Device type 01 and 02 4.0 V
 Device type 03 and 04 4.75 V
 Operating temperature range:
 Device type 01 -55°C to 125°C

1.5 Radiation tolerance

Maximum total dose available (high dose rate = 50 - 300 rad(Si)/s):
 Device type 01 and 02:
 Device (device 02 and v) 300 krad(Si) 13/
 Device type 01 100 krad(Si) 13/
 Device type 03 and 04 300 krad(Si) 13/
 Device type 05 100 krad(Si) 13/
 Maximum total dose available (low dose rate 1.0 E11 rad(Si)/s):
 Device type 01 and 02 50 krad(Si) 13/
 Device type 03 100 krad(Si) 13/
 Single event phenomena (SEP):
 Device type 05:
 No SEL occurs at normal LET (see 4.4.4.3) $≤ 60 \text{ MeV}/(\text{mg}/\text{cm}^2)$ 13/
 SET observed at LET (see 4.4.4.3) (saturated cross section = $1.1 \times 10^{-8} \text{ cm}^2$) $≥ 18 \text{ MeV}/(\text{mg}/\text{cm}^2)$ 13/
 (SET observed at LET (see 4.4.4.3) (saturated cross section = $1.1 \times 10^{-8} \text{ cm}^2$) $≥ 18 \text{ MeV}/(\text{mg}/\text{cm}^2)$ 13/)

1.6 Maximum total dose based on performance (SEE, LATCHUP) in normal operation

1.7 Device type 07 and 02 may be dose rate sensitive in a specific environment and may demonstrate enhanced dose rate effects. Device type 07 and 02 radiation and dose rate tests for the rated parameters are guaranteed only for the conditions as specified in MIL-STD-883C method 1019, condition A to a maximum total dose of 300 krad(Si) for device 07 or 100 krad(Si) for device 02.

1.8 Device types 02 and 04 radiation and dose rate tests for the rated parameters are guaranteed only for the conditions as specified in MIL-STD-883C method 1019, condition A to a maximum total dose of 300 krad(Si), and condition 1019.1, condition A to a maximum total dose of 100 krad(Si).

1.9 The manufacturer warrants device type 05 has performed characterization testing in accordance with MIL-STD-883C method 1019.1 condition A (high dose rate = 100 rad(Si)/s) and condition 1 (low dose rate = 10 rad(Si)/s) to a dose level of 100 krad(Si). Manufacturer may perform accelerated annealing, 1.0 hour test and determine no dose dependent effects. The annealing and test conditions and test parameters are given below. The specification marks as specified in Table 1a. The radiation and dose rate tests for the rated parameters are guaranteed only for the conditions as specified in MIL-STD-883C method 1019, condition A and 1019.1.

1.10 The manufacturer warrants device type 05 after any single event transient and dose rate effect the SEE characterization, but are not production tested unless specified by the customer through the quotation order or contract. For more information on SEE test results, customers are requested to contact the manufacturer.

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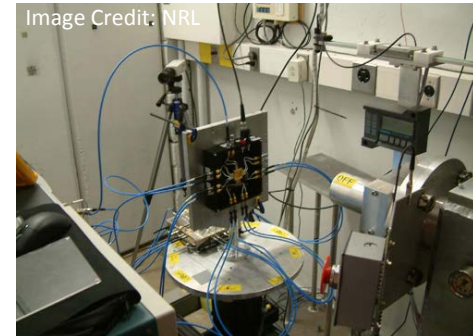
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 SHEET: 1 OF 24

Device type 05 100 krad(Si) 13/

Single event phenomena (SEP):
 Device type 05:
 No SEL occurs at normal LET (see 4.4.4.3) $≤ 60 \text{ MeV}/(\text{mg}/\text{cm}^2)$ 13/
 SET observed at LET (see 4.4.4.3) (saturated cross section = $1.1 \times 10^{-8} \text{ cm}^2$) $≥ 18 \text{ MeV}/(\text{mg}/\text{cm}^2)$ 13/

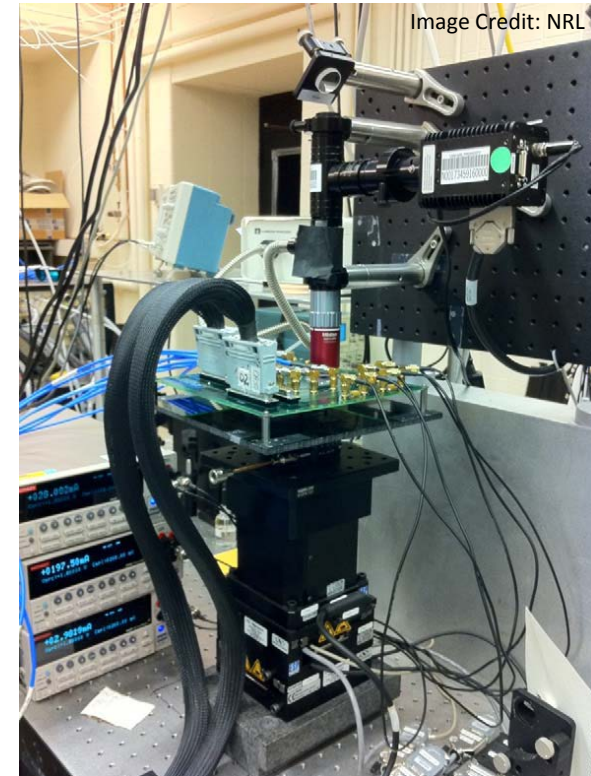
Accelerators for SEE Screening

- When no SEE data are available, SEE testing must be carried out.
- SEE testing normally involves the use of ion beams at an accelerator.
- SEE testing provides information about:
 - Presence of SEEs
 - Characteristics of SEEs – destructive (SEL) or non-destructive (SEU)
 - Cross-section vs LET needed for error-rate calculations
- Issues with accelerator testing are:
 - **Cost** – from \$1500 to \$5500 per hour
 - **Access** – only a few facilities available
 - **No spatial or temporal information** – broad beam



Reverse the Screening Process

- First screen ICs for SEEs using pulsed laser.
- Pulsed laser offers:
 - Quick turnaround
 - Only one device required
 - Same preparation – grinding and polishing back side
 - Spatial and temporal information
- If destructive SEEs occur (SEL, SEB or SEGR), decision needs to be made whether to accept the part.
- If non-destructive SEEs occur (SEUs, SETs, SEFIs), threat must be evaluated and, if necessary, mitigated.

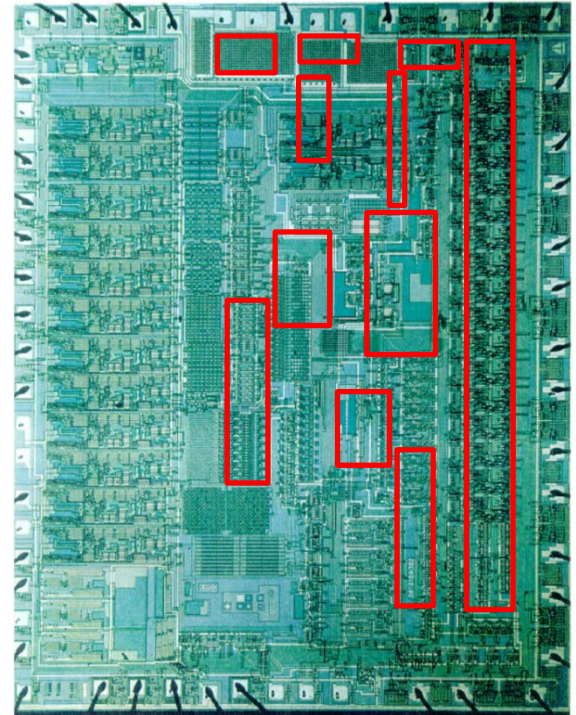


Single-Event Latchup Screening

Resolver-to-Digital Converter

DDC RDC19220

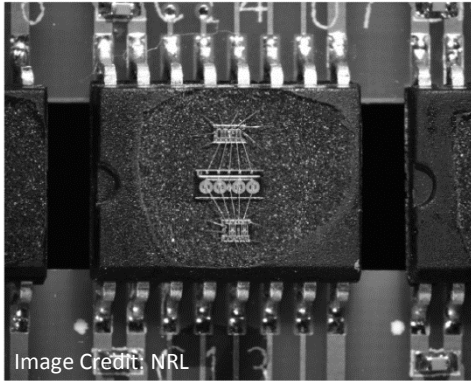
- NASA asked NRL to test the RDC for SEL sensitivity because the part was being considered for future space missions.
- The latch-up sensitive areas are shown here
- Based solely on these laser results, this part was eliminated from consideration for all future NASA missions



Buchner, et al., TNS, 46, 1445 (1999).

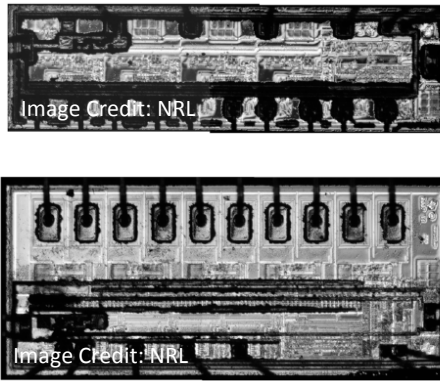
Single-Event Latchup Screening

Latchup Observed



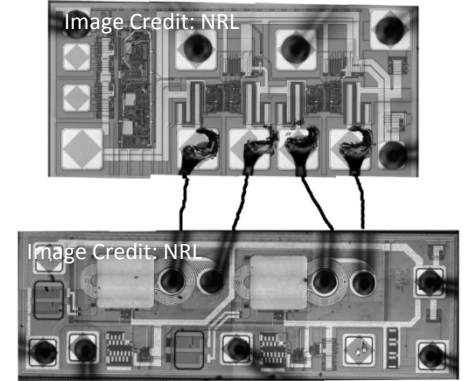
i-coupler from Analog Devices

Latchup Observed



Opto-isolator from Texas Instruments

No Latchup Observed

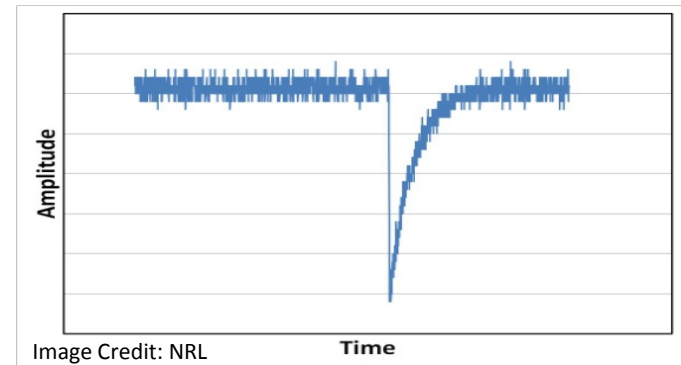
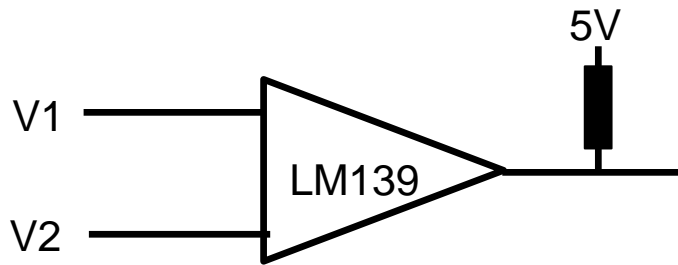


NVE Digital Isolator

- *Coupling medium not sensitive to SEL*
- *The driver and receiver circuits are, except for NVE device*

Single Event Test – Worst Case

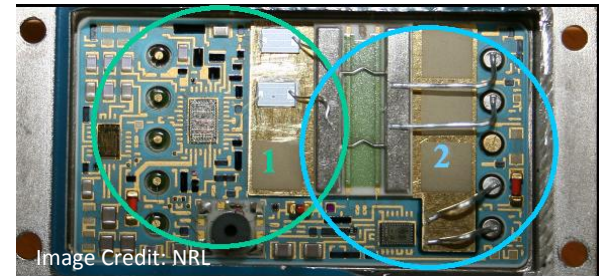
- **Use a laser to measure worst-case SETs**
 - Heavy ions cause analog SETs that depend on configuration
 - Linear devices, such as op-amps, voltage regulators, and comparators give rise to analog SETs that depend on specific configuration.
 - Cannot retest a part for each application because of time and expense.
 - Pulsed laser can provide worst-case transients, i.e., in orbit, the SETs won't be worse than those found on earth.
 - Can the system tolerate the SETs?



Single-Event Functional Interrupt

- **Solid State Power Controller (SSPC) from DDC (RP-21005DO-601P)**
 - DDC replaced FET from Signetics with non rad-hard FET from International Rectifier.
 - Parts engineer suspicious and asked for testing.
 - Heavy-ion testing at Texas A&M revealed the presence of SETs causing the SSPC to switch off.
 - Pulsed laser testing revealed that the ASIC was sensitive to SETs, and that large SETs caused the SSPC to switch off.
 - Previous SEE testing by GSFC of ASIC at Brookhaven revealed no SETs.
 - Replaced DDC SSPC with Micropac SSPC
 - SEE testing successful at TAMU

Problem attributed to short range of ions
at Brookhaven National Laboratory



Summary

- An alternate approach to TID screening of parts for operation in the space radiation environment is pulsed-laser SEE screening because it offers a rapid and relatively inexpensive test.
- The approach has been illustrated and validated with several examples involving both destructive and non-destructive single-event effects.