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 Cuircuit
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_XXXXXXX** L=(50 krad(Si), R=100 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.

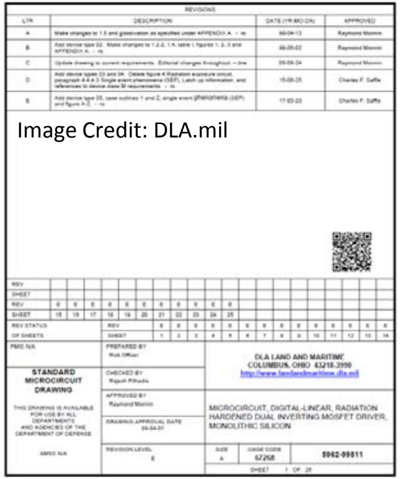
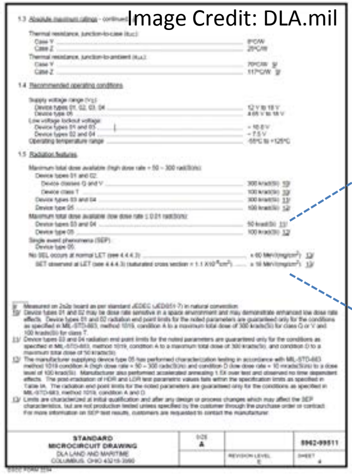


Image Credit: DLA.mil



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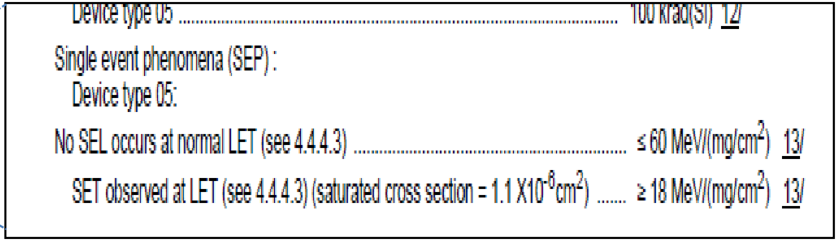


Device type 05 .... 100 krad(Si) 12/

Single event phenomena (SEP):

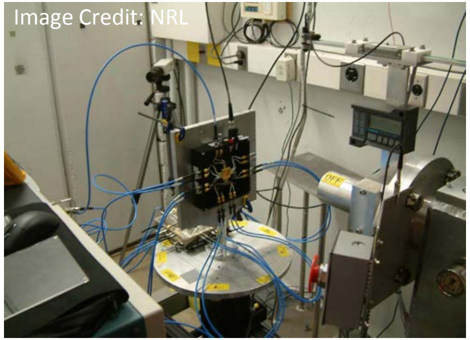
Device type 05:

No SEL occurs at normal LET (see 4.4.4.3) .... ≤ 60 $MeV/(mg/cm^2)$ 13/

SET observed at LET (see 4.4.4.3) (saturated cross section = 1.1 X$10^{-8}cm^2$) .... ≥ 18 $MeV/(mg/cm^2)$ 13/

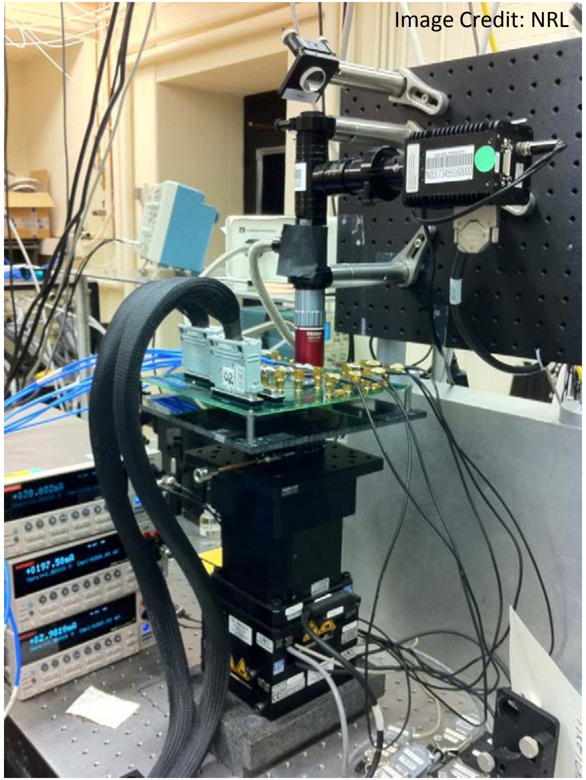
Accelerators for SEE Screening

- 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

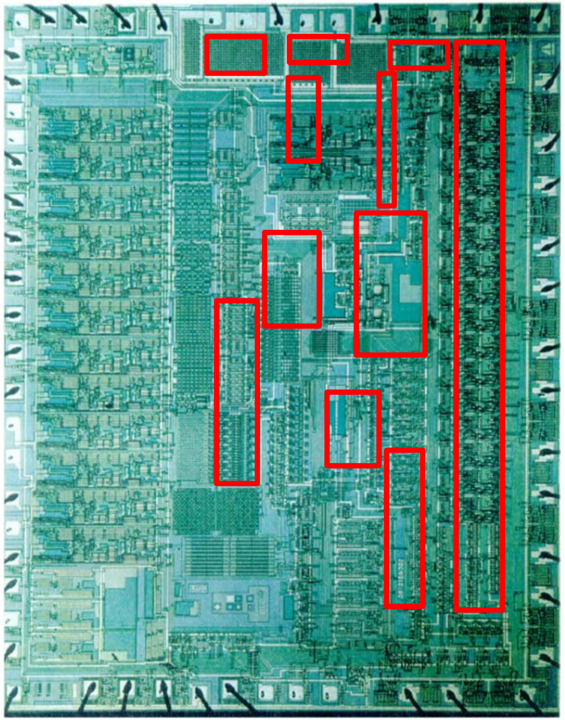
- First screen ICs for SEEs using pulsed laser.
- Pulsed laser offers:
  - Quick turnaround
  - Only one device required
  - Same preparation – grinding and polishing back side
  - Spatial and temporal information
- If destructive SEEs occur (SEL, SEB or SEGR), decision needs to be made whether to accept 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

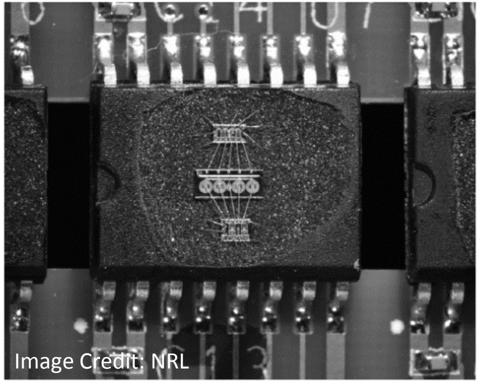
- NASA asked NRL to test the RDC for SEL sensitivity because the part was being considered for future space missions.
- The latch-up sensitive areas are shown here
- Based solely on these laser results, this part was eliminated from consideration for all future NASA missions



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

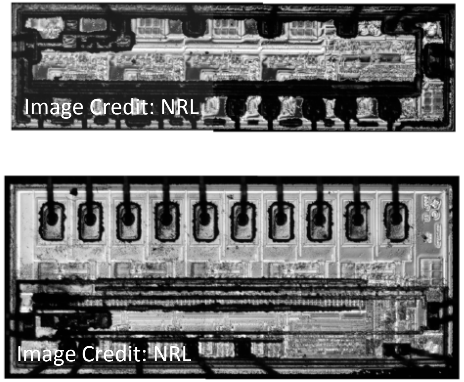
Single-Event Latchup Screening

Latchup Observed



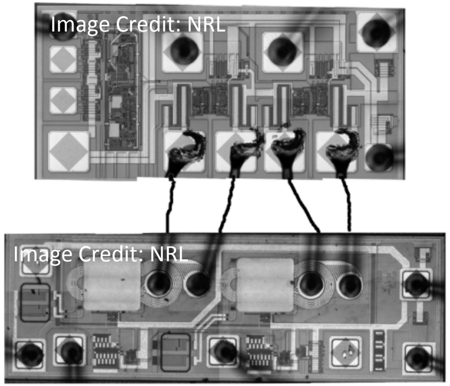
i-coupler from Analog Devices

Latchup Observed



Opto-isolator from Texas Instruments

No Latchup Observed

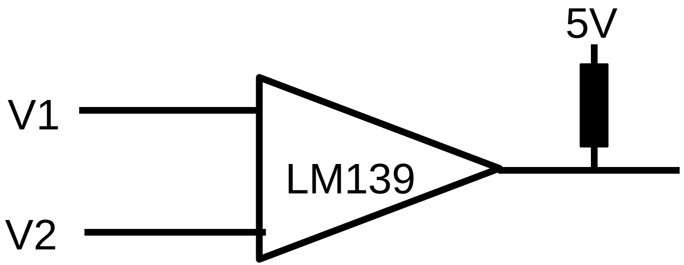


NVE Digital Isolator

- *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 that those found on earth.
  - Can the system tolerate the SETs?



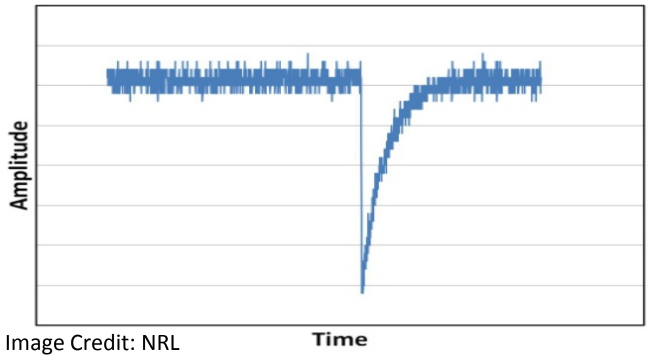


Image Credit: NRL

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

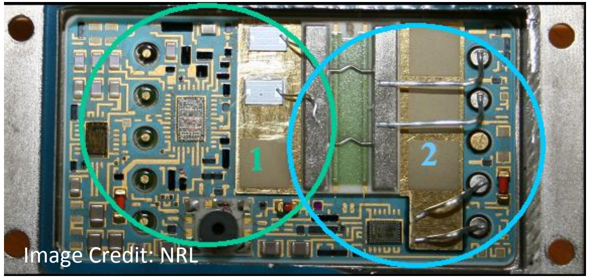


Image Credit: NRL

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.