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

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### Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ASIC</td>
<td>Application Specific Integrated Circuit</td>
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<tr>
<td>DDC</td>
<td>Data Device Corporation</td>
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<td>DDD</td>
<td>Displacement Damage Dose</td>
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<td>ESA</td>
<td>European Space Agency</td>
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<td>FET</td>
<td>Field Effect Transistor</td>
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<td>GSFC</td>
<td>Goddard Space Flight Center</td>
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<td>IC</td>
<td>Integrated Circuit</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<td>LET</td>
<td>Linear Energy Transfer</td>
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<td>MAPLD</td>
<td>Military and Aerospace Programmable Logic Devices</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>NRL</td>
<td>Naval Research Laboratory</td>
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<td>RADECS</td>
<td>Radiations Effects on Components and Systems</td>
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<td>RDC</td>
<td>Resolver-to-Digital Converter</td>
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<td>SEB</td>
<td>Single-Event Burnout</td>
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<td>SEE</td>
<td>Single-Event Effect</td>
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<td>SEFI</td>
<td>Single-Event Functional Interrupt</td>
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<td>SEGR</td>
<td>Single-Event Gate Rupture</td>
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<tr>
<td>SEL</td>
<td>Single-Event Latchup</td>
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<tr>
<td>SET</td>
<td>Single-Event Transient</td>
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<tr>
<td>SEU</td>
<td>Single-Event Upset</td>
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<tr>
<td>SSPC</td>
<td>Solid-State Power Converter</td>
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<td>TAMU</td>
<td>Texas A&amp;M University</td>
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<td>TID</td>
<td>Total Ionizing Dose</td>
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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 (SEE)
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 \( L=(50 \text{ krad(Si)}, R=100 \text{ krad(Si)}) \)
  - 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 \(^{60}\text{Co}\) source – remote or own \(^{60}\text{Co}\) cell
  - Performing testing at high (50 – 300 rad(Si)/s) or low dose rates (0.01 rad(Si)/s)
If the IC passes TID specifications, next step is to evaluate IC for SEE:

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

Single-Event Latchup Screening

Latchup Observed

- i-coupler from Analog Devices
- Opto-isolator from Texas Instruments

Latchup Observed

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?

![Diagram of LM139 circuit with inputs V1 and V2 and output 5V]

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.