Total Ionizing Dose influence on the Single Event Effect sensitivity of active EEE components

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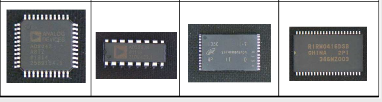
Radiation hardness of active EEE electronic devices with regards to space environment is characterized according to two main aspects: cumulated effects and single event effects. The radiation qualification process includes Total Ionizing Dose (TID) and Single Event Effect (SEE) tests, usually performed independently. The aim of this study is to evaluate the potential effect of TID on SEE sensitivity and assess the consequences in terms of radiation hardness assurance for various space missions and especially the JUICE mission to Jupiter. Several radiation test campaigns, combining TID and SEE testing, were conducted on four devices types: an ADC, a DAC, an SRAM and a NAND Flash.

Selected devices

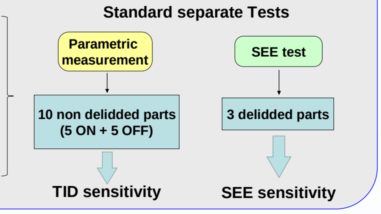
Reference	AD9042	AD558	MT29F4G08AAC	R1RW0416
Manufacturer	Analog Device	Analog Device	Micron	Renesas
Type	ADC 12bit	DAC 8bit	NAND flash	SRAM 4Mb 16bit



- 4 types of devices commonly used in space missions were selected
- TID Sensitive
  - ⇨ Parameter drifts but parts remain functional
- SEE sensitive
  - ⇨ Low LET threshold
  - ⇨ Low saturated cross section
- Monitoring of SEE sensitivity with increasing TID level

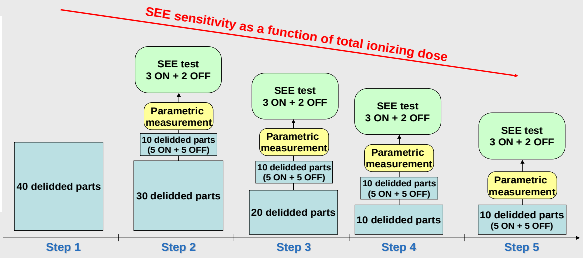
Preliminary measurements

- TID test allowed to define
  - ⇨ TID sensitivity
  - ⇨ Total dose level and dose steps for each reference for the combined TID and SEE tests
- SEE test allowed to define
  - ⇨ SEE sensitivity



Combined TID and SEE test plan

Irradiation conditions for AD9042, AD558 and R1RW0416	
Dose rate	74 rad(Si)/h
Total dose	150 krad(Si)
TID steps	0, 41, 78, 114, 150 krad(Si)
Irradiation conditions for MT29F4G08	
Dose rate	66 rad(Si)/h
Total dose	100 krad(Si)
TID steps	0, 36, 72, 100 krad(Si)



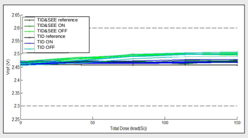
- At each TID step, 10 devices per reference were removed from the TID facility and measured
- Among these 10 devices, 3 biased parts and 2 unbiased parts were selected for the test under heavy ions
- Irradiated and measured (parametric test or cross section) devices were no longer used for the study

External parasitic parameters

- During TID irradiation devices remained open for a long time in a non-controlled atmosphere
  - ⇨ possible degradation effects due to the irradiation room environment

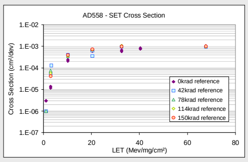
Long time Open condition VS TID

- 10 non-delidded reference parts exposed to TID were measured at each dose step
  - ⇨ No significant TID drifts difference between reference and the tested parts
  - ⇨ No influence of the open condition on the TID degradation



Long time Open condition VS SEE

- Delidded reference parts, non exposed to TID, were SEE tested after each dose step
  - ⇨ No significant SEE cross section differences between all reference and the tested parts
  - ⇨ No influence of the open condition on the TID degradation

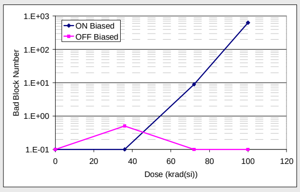


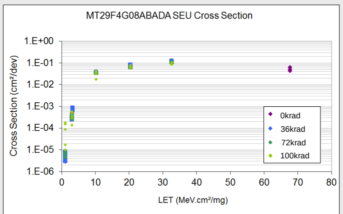
No impact of external parameters has been observed during this study

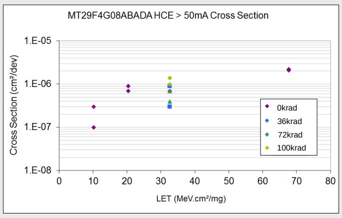
Results Analysis

MT29F4G08 NAND FLASH test results

- No influence of the dose level on
  - ⇨ SEU and SEFI cross section (saturation, LET threshold)
  - ⇨ Number of HCE
- Dose level and bias condition have an influence
  - ⇨ Bad block number

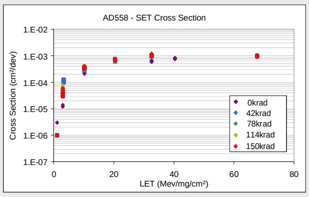


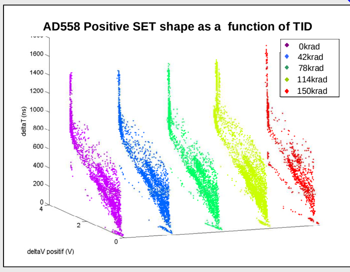




AD558 DAC test results

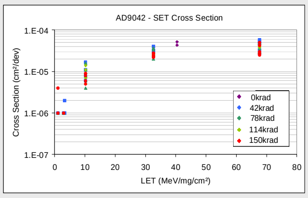
- No influence of the dose level on
  - ⇨ SET cross section (saturation, LET threshold)
  - ⇨ SET signature repartition
  - ⇨ SET amplitude, duration

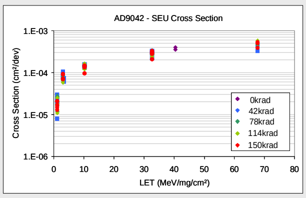




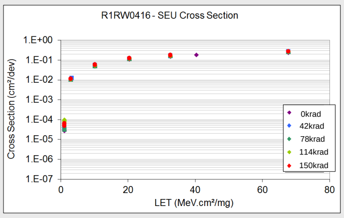
AD9042 ADC test results

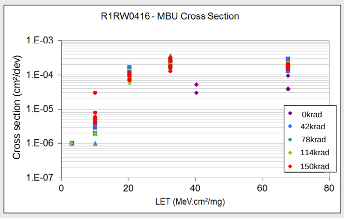
- No influence of the dose level on
  - ⇨ SEU and SET cross section (saturation, LET threshold)
  - ⇨ SET duration





R1RW0416 SRAM test results





- No influence of the dose level on
  - ⇨ SEU and MBU cross section (saturation, LET threshold)
  - ⇨ MBU multiplicity
- Heavy ion flux have an influence on the MBU apparition
  - ⇨ Low flux test is primordial for MBU characterization (<1.0E+3cm-2)

Conclusion

- 280 tested parts, 214 delidded parts, 12 weeks of Cobalt-60 irradiation, 145 hours of heavy ion beam to investigate possible TID-SEE synergetic effects
- External parameters had no impact on the SEE sensitivity or on the TID degradation
- No TID impact on SEE sensitivity has been observed
- MT29F4G08 number of Bad Blocks increases with Total Ionizing Dose level for biased devices. Heavy ions produced also errors in the flash memory.
  - ⇨ Number of errors increases due to both contributions
  - ⇨ Effect observed for high dose level around 40 krad(Si)
  - ⇨ Combined effect will be more important during the JUICE mission, especially for biased components

Perspectives

- TID-SEE synergetic effect on MOSFETs
  - ⇨ Impact of TID on SEB and SEGR
- Synergetic effect of TNID on the SEE sensitivity
- Effect of SEE on parametric degradation

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