ATLAS Radiation Tolerant Electronics

Proposed Guideline on COTS Lot to Lot Variation

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Outline

- Introduction
  - 2000: ATLAS Policy on Radiation Tolerance Electronics
  - 2013: Radiation Estimate Task Force
  - 2020: Radiation Effects Task Force
- COTS Lot to Lot Variation
  - Proposed Guideline
  - Comments
- Summary
- *Note:* ***work in progress*** *– discussion with Federico & Mika ongoing*

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Introduction (1)

- ATLAS Radiation Hard Electronics Web Page
  - http://atlas.web.cern.ch/Atlas/GROUPS/FRONTEND/radhard.htm
  - Last updated in April 2004

Introduction (2)

- ATLAS Policy on Radiation Tolerant Electronics
  - EDMS 113816 v.3 | ATC-TE-QA-0001 v.3
  - https://edms.cern.ch/document/113816/3
  - Released in July 2000
  - $RTC_x = SRL_x \times SF_{sim} \times SF_{ldr} \times SF_{lot}$
    - X: tid, niel
    - [1] ATLAS policy specifies annealing tests that might allow for reducing the $SF_{ldr}=1$
  - $RTC_{see} > SEU_f$, $SEU_f = (SEU_m/ARL) \times (SRL_{see}/10^8 s) \times SF_{sim}$
    - ARL (Applied Radiation Level): enough statistics or 2x SRL_{see} if no SEU occurs
    - [2] 4 samples are recommended for SEE test, not really accounted for lot variation

Safety Factors in 2000	Simulation	Low Dose Rate Effects [1]		Lot to Lot Variation		
		ASIC	COTS	ASIC	COTS	
					Single-Lot	Multi-Lots
TID	3.5	1.5	5	1		4
NIEL	5	1		1		4
SEE	5			[2]		

Introduction (3)

- ATLAS Radiation Estimate Task Force in 2013
  - EDMS 1293497 v.1 | ATU-GE-ER-0005 v.1
  - https://edms.cern.ch/document/1293497/1
  - Released in June 2013

- Even though technologies evolved over the past 10 years, several COTS for upgrades would still be based on relatively 'old' processes.
- Besides, ATLAS has specific policies e.g. to prove whether a device is sensitive to ELDR effects
- **Decided to maintain SF for ELDR and Lot-variation as they are**
- **Focus on SF for simulation uncertainties**

  - Fluence for SEE qualification test has been using safety factor 8 = (SF_{sim}xSF_{lot}) generally
  - Given the constraints of beam time and relevant statistics, it is acceptable to test multiple samples to reach the fluence collectively

Safety Factors in 2013	Simulation		Low Dose Rate Effects		Lot to Lot Variation		
	ID	Elsewhere	ASIC	COTS	ASIC	COTS	
						Single-Lot	Multi-Lots
TID	1.5		1.5	5	1		4
NIEL	1.5	2	1		1		4
SEE	2				1		4

Introduction (4)

- ATLAS Radiation Effects Task Force in 2020
  - CDS: https://cds.cern.ch/record/2718449
  - Released on July 16, 2020
  - $RTC_x = SRL_x \times SF_{sim} \times SF_{test}$ ($\times SF_{lot}$)
    - X: tid, Φ^{Si}_{neq}, Φ^{had}_{20}
    - Test: ldr, niel, seu
    - [1] High temperature annealing should always be part of the qualification, tests at the lowest practical dose rate
    - [2] Dedicated procedure based on irradiation at two sufficiently different dose rates

$$\boxed{SF_{ldr} = 1 + (SF_{ldr,exp} - 1)\left[\frac{\log_{10}(HDR/ADR)}{\log_{10}(HDR/LDR)}\right]}$$

    - Note: All LDR-related modifications for TID test apply to CMOS components only. For bipolar, please refer to procedures in 2000 policy

Safety Factors in 2020	Simulation	Low Dose Rate Effects		NIEL		SEU		
		TID < 10kGy	TID > 10kGy	protons + neutrons	Monoenergetic beam	E_had > 60 MeV E_cut = 2 MeV	E_had > 60 MeV E_cut = 20 MeV	Heavy ion
TID	1.5	1 [1]	test [2]					
Φ^Si_neq	1.5			1	1.3			
Φ^had_20	1.5					1	2	5

Introduction (5)

- ATLAS Radiation Effects Task Force in 2020
  - $RTC_x = SRL_x \times SF_{sim} \times SF_{test}$ ($\times SF_{lot}$)
  - Lot to lot variation – page 13 of the report
    - No safety factor can compensate for the variability in the radiation response from different lots, e.g. manufacture may change foundry
    - SF_{lot} has to be considered to be ***unapplicable***
    - It is strongly recommended to test a representative number of components from every lot
    - Taken strictly this increases significantly the ***need of testing and extends it from qualification to (pre)production***
  - Review committee will have to check on a case-by-case basis, and make decision based on available detailed information
    - Evaluate radiation test results
    - Assess the risk and impact (cost, down-time, performance degradation etc.)

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COTS Lot to Lot Variation

- Proposed guideline for lot to lot variation is focused on COTS in systems with TID < 10kGy
  - RETF 2020 report covers ASIC related lot to lot variation with high TID quite well
- Distinguish two goals now, that were always closely linked in the past:
  - 1) How to avoid wasting ATLAS money by procuring a full quantity of devices that turn out to be not sufficiently rad-hard
  - 2) How to avoid building a detector from the procured devices that fails before the end of HL-LHC because the devices were not sufficiently rad-hard

Proposed Guideline (1)

- Final Design Review
  - Perform tests on samples from different procurement lots, e.g. different distributors or different date codes before FDR
  - # of procurement lots and # of samples per lot to be determined, e.g. at least 2 procurement lots, 11 samples per lot [1], or 2 samples per reel for multiple reels
  - Test samples to failure or to
    - TID: SRL_{tid} x SF_{sim} (1.5) x SF_{ldr} (1) x SF_{lot} (3)
    - NIEL: SRL_{niel} x SF_{sim} (1.5) x SF_{niel} (1 or 1.3) x SF_{lot} (3)
    - SEE: SRL_{see} x SF_{sim} (1.5) x SF_{see} (1 or 2 or 5) x SF_{lot} (3)
  - If TID/fluence of failure is less than the one with SF_{lot} (3) [2], one should present the risk mitigation strategy, including monitoring, maintainability, accessibility and ability to procure a single lot during the FDR
  - The goal is to assess the confidence and risks before moving forward to procure COTS components for (pre)production after FDR
- [1] 2000 ATLAS Policy on Radiation Tolerance Electronics
- [2] 2020 ATLAS Safety Factor and Testing Procedure Recommendations of the Radiation Effects Task Force, page 14

Proposed Guideline (2)

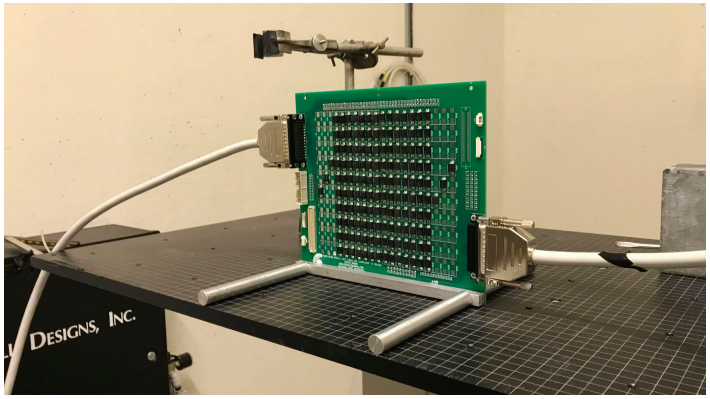
- Production Readiness Review
  - Procure COTS components for final production, perform tests on samples from a single lot or different procurement lots before PRR
  - # of samples per lot to be determined, see examples before
  - Test samples to failure or to
    - TID: SRL_{tid} x SF_{sim} (1.5) x SF_{ldr} (1) x SF_{lot} (1)
    - NIEL: SRL_{niel} x SF_{sim} (1.5) x SF_{niel} (1 or 1.3) x SF_{lot} (1)
    - SEE: SRL_{see} x SF_{sim} (1.5) x SF_{see} (1 or 2 or 5) x SF_{lot} (1)
  - If TID/fluence of failure is less than the one with SF_{lot} (1), one will have to reject the lot
  - If one only has the funds to buy COTS components after PRR, this will become a follow-up action to be closed after PRR
    - One should balance the cost associated with irradiation tests (labor + beam time + travel) and COTS components, plus the risks of rejection of a certain lot at a later stage

Comments (1)

- Pre-FDR tests do not absolutely ensure goal 1), but it will establish that whoever has performed (at least) these tests has applied due diligence, same principle as ATLAS policy released in 2000
- Pre-PRR tests will ensure goal 2)
- The team is strongly encouraged to pursue ***single lot*** procurement if possible, which will significantly reduce the efforts in the qualification tests before PRR

Comments (2)

- For components impossible to procure in a single fabrication lot, one will have to deal with the procurement lots. It is recommended to contact vendor and ask for as detailed information about different/same lots as the vendor is willing to give away
- Team will have to consider different scenarios
  - For procurement lots delivered from different distributors, one has to test samples from different deliveries
  - For procurement lots delivered with different date codes, one has to test samples with different date codes
  - For procurement lots delivered with many reels/tubes/trays, one has to test samples from different reels/tubes/trays
  - For small components (diodes, transistors) used on board with large quantities, one can easily put ~100 parts on a test board, e.g. one can take 10 samples from each reel
  - For large components (FPGA) used on board with small quantities, one can take 1 or 2 samples from each procurement lot



- Example: TVS TID test by Tile team presented in ELMB2-MB FDR
  - 200 diodes, 2 part numbers from 9 manufacturers, > 10 samples for each part number with $SF_{lot} > 6$
  - One manufacturer is chosen, will procure single lot and perform irradiation test before PRR

Summary

- 2020 ATLAS RETF report provided new recommendations on safety factor and testing procedure based on knowledge gained over the past 20 years
  - SF_{lot} has to be considered to be ***unapplicable***
  - It is strongly recommended to test a representative number of components from every lot
- A guideline for COTS irradiation test is proposed to account for the lot to lot variation and associated risks
  - Covers irradiation tests expected ***before FDR and PRR***
  - The team is strongly encouraged to pursue ***single lot*** procurement if possible
  - The team should plan for the irradiation tests accordingly ***before FDR/PRR***
- *Note:* ***work in progress*** *– discussion with Federico & Mika ongoing*

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