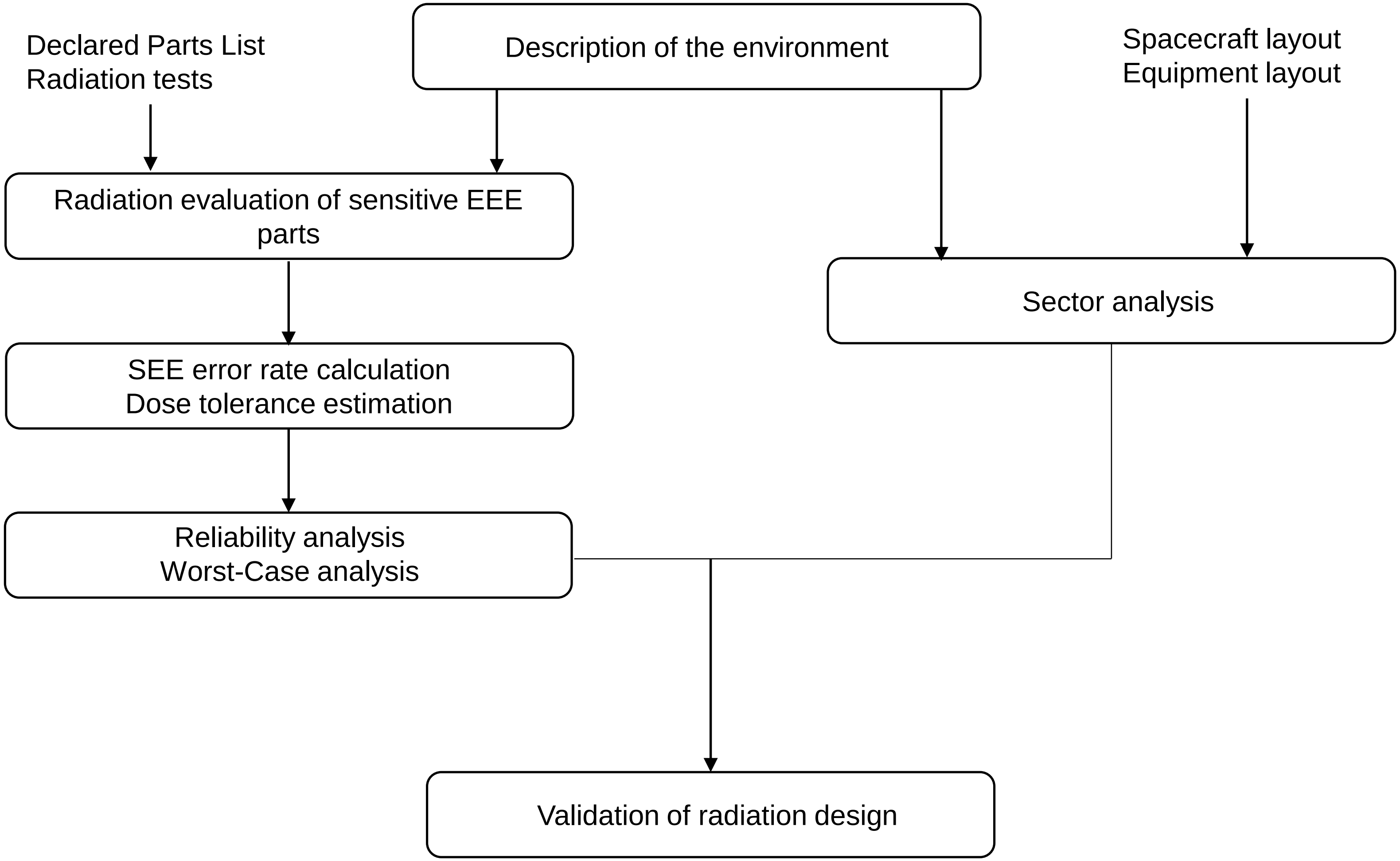
Radiation Hardness Assurance

1. Radiation effects industrial approach
2. Qualification systems
3. Rad-Hard & Rad-Tolerant devices

Radiation Engineering Industrial Approach

- In an industrial approach, three mains phases are inter-connected:
  - Mission specification and design
    - Aspects related to the parameters specified for the mission (for radiation tasks especially environement, orbit, duration)
    - Aspects related to the electrical design of the system, concept of design margin
  - Part evaluation and testing
    - Aspects related to the device selection and tests under irradiation
  - Calculation
    - Link between the environment, the design margin and the device behaviour under irradiation
- Those three axis of study lead to a conclusion on the hardness of the whole system

Radiation Engineering Industrial Approach



Declared Parts List
Radiation tests

Description of the environment

Spacecraft layout
Equipment layout

Radiation evaluation of sensitive EEE parts

Sector analysis

SEE error rate calculation
Dose tolerance estimation

Reliability analysis
Worst-Case analysis

Validation of radiation design

TID and TNID Industrial Approach

- The worst-case analysis (WCA) is performed in order to determine the system degradation susceptibility to radiation, temperature and aging

- The worst-case analysis is performed to demonstrate that the system will be able to remain functionnal for the mission lifetime at the specified orbit
  - The radiation test results are inputs for the WCA
  - The WCA is performed by the system engineers: the designers define the acceptable radiation induced parameter drifts
  - Finally the WCA (the design dose) is an input for the radiation analysis

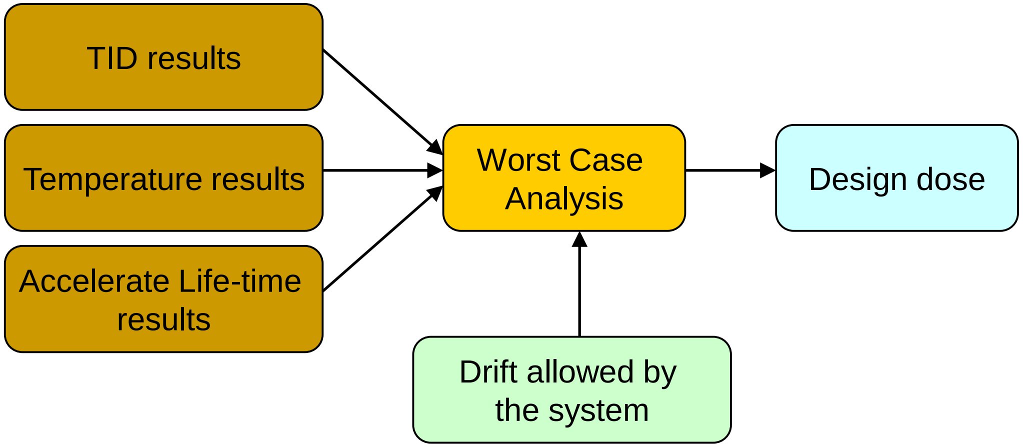
- The WCA can be specific to an application
  - Calculated design dose applicable for the system electrical design only

- The WCA can be applicable to several design
  - The design dose is calculated according to the different electrical designs involving the device

TID and TNID Industrial Approach

TID and TNID:

<u>Worst-case analysis</u>


TID results

Temperature results

Accelerate Life-time results

Worst Case Analysis

Design dose

Drift allowed by the system

The worst-case analysis is performed to show that the system is able to be functional for the duration of the mission and for the orbit used.

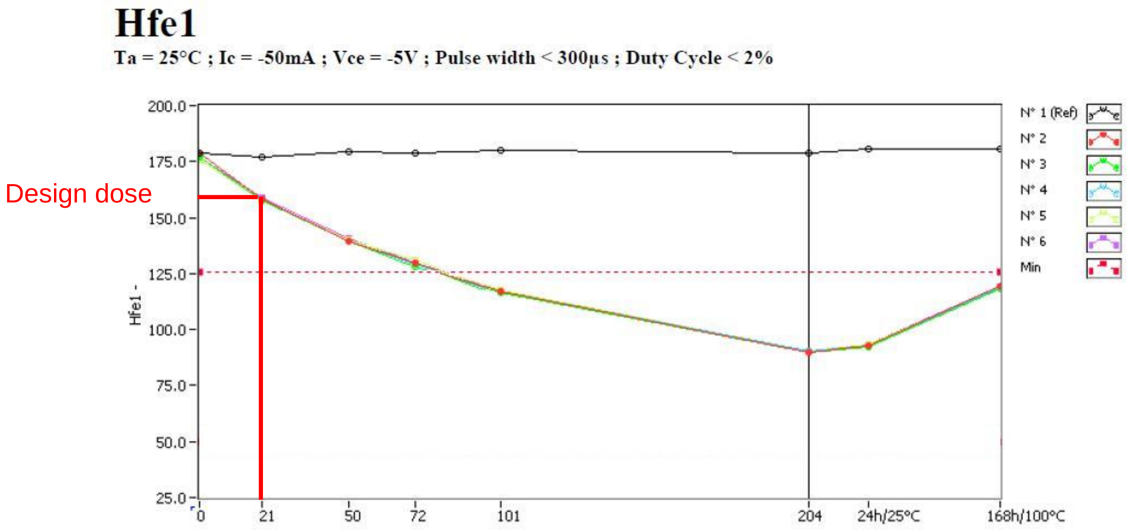
TID and TNID Industrial Approach

→Definition of a design dose

The design dose is the maximum deposited dose that can be tolerated by the device to ensure its functionality in the unit.

TID and TNID:

Design dose ≠ component specification



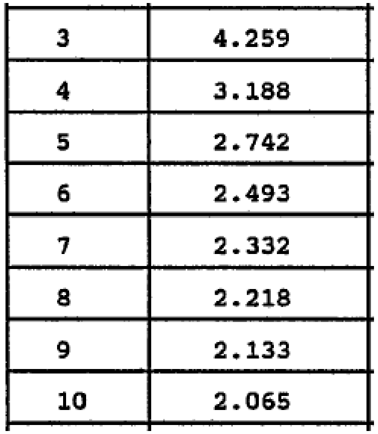
TID and TNID Industrial Approach

- The design dose (resp. fluence for displacement)
  - Is the maximum dose level at which all electrical parameters remain acceptable according to the worst-case analysis
  - Is calculated to take into account
    - Lot-to-lot variability
    - Within-one-lot variability

- The within-one-lot variability can be considered with the « 3-sigma » method
  - For increasing drift of parameter x
    - Δx+3σ
  - For decreasing drift of parameter x
    - Δx-3σ

MIL-HDBK-814

C = 0,9 ; P=0,9



3	4.259
4	3.188
5	2.742
6	2.493
7	2.332
8	2.218
9	2.133
10	2.065

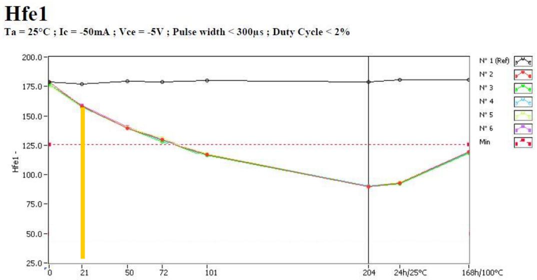
TID and TNID Industrial Approach

- Does each different lot need to be tested ?
  - Usually not…
- The lot-to-lot variability is considered in the radiation test frequency, specified by the prime contractor of a spacecraft
- This test frequency depends on
  - The device type
  - The device technology

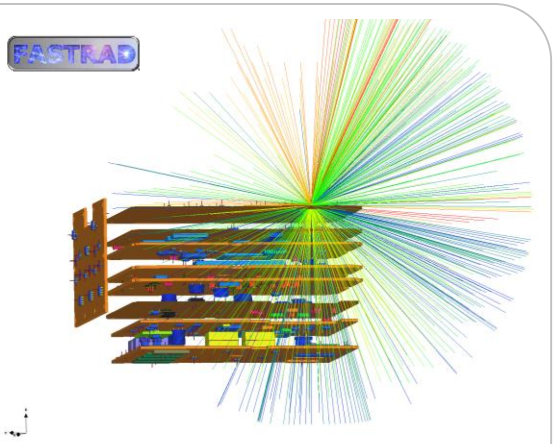
TID and TNID Industrial Approach

TID and TNID:

Radiation Analysis



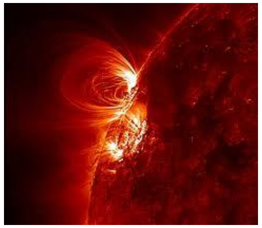
Design dose



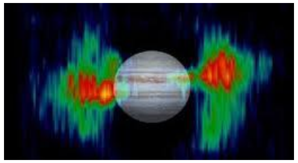
Estimated dose received by the component

- Estimated dose < Design dose
- Estimated dose > Design dose ➔Shielding

SEE Risk Industrial Approach



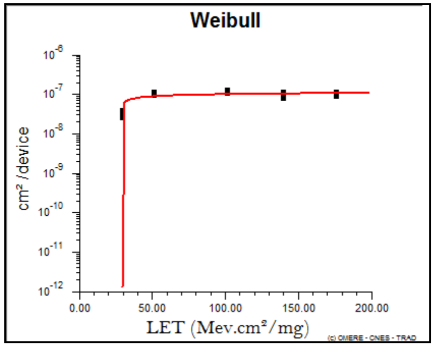
Solar protons



Trapped protons

Ions GCR

+



$LET_{threshold}$	29.4
$\sigma_{saturation}$	1.39e-7
W	12.35
s	0.2

- Device description
- Sensitive volume depth
- Sensitive cell number

SEE Rate

- System level

SEE Analysis

SEE Risk Industrial Approach

- Proton SEE rate calculation
    - When experimental data exists and are applicable the SEE rate calculation is performed
- When no experimental data exists
    - Estimation of the proton SEE rate from the heavy ion sensitivity
        - PROFIT (TAS)
        - SIMPA (Airbus DS)
        - METIS (Airbus DS)

SEU Risk Industrial Approach

- For radiation-induced single event effects, it is usually assumed that there is no lot-to-lot variability
  - SEE characteristics are technology dependent
    - Diffusion masks
    - Intrinsic technology characteristics

- SEU analysis
  - The SEU is non-destructive event
    - There usually is no requirement in terms of LET threshold or saturation cross section (no maximum SEU rate)
    - The SEU rate (heavy ions and if relevant protons) are calculated
    - The SEU rates are inputs for the reliability analysis
      - Demonstrate that the impact on the system is not critical

SET Risk Industrial Approach

- SET is non-destructive events
    - SET is <u>strongly design dependent</u> (bias condition, input signal, load)
- Step 1
    - Worst-case SET shape analysis
        - The impact of a SET shape (amplitude and duration) assumed to be worst-case is studied for the application
        - If there is no critical impact, the SET analysis consists in describing the different SET impacts on the system
- Step 2 (if relevant)
    - If the impact of the worst-case shape is <u>critical</u>, then a SET test is performed
        - The « real » SET shape is determined under irradiation
        - The impacts on the system of the « real » shape are studied, and associated to the SET rate

SEL Risk Industrial Approach

- SEL is a destructive events
  - Prime contractor part selection specification generally asks for latch-up free devices, or determine a latch-up LET threshold value
    - Typically over 60 $\mathrm{MeV.cm^2.mg^{-1}}$
- Device presenting destructive events are usually accepted if the associated failure rate is smaller than the tenth of the part intrinsic reliability figure λ

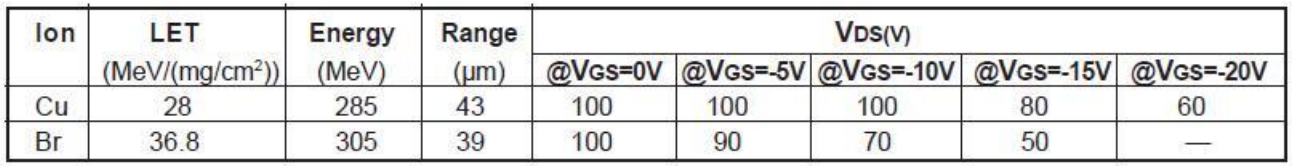
$$\lambda_{rad} < \frac{\lambda}{10}$$

SEB/SEGR Risk Industrial Approach

- SEB is destructive event occuring in N-channel power mosfet
  - Application of test data provided by manufacturer (SOA)
  - Application of derating rules
    - For example Vds(max) < 50% BVdss
  - If the derating rule is not applicable, a test is performed

- SEGR is a destructive event occuring in N and P-channel power mosfet
  - Application of test data provided by manufacturer (SOA)
  - Application of derating rules
    - For example
      - Vgs < 0V for PMOS
      - Vgs > 0V for NMOS
  - If the derating rules are not applicable, a test is performed

SEB/SEGR Risk Industrial Approach



Ion	LET (MeV/(mg/cm^2))	Energy (MeV)	Range (µm)	VDS(V)				
				@VGS=0V	@VGS=-5V	@VGS=-10V	@VGS=-15V	@VGS=-20V
Cu	28	285	43	100	100	100	80	60
Br	36.8	305	39	100	90	70	50	—

2N7261 (IRHF7130) SOA
International Rectifier
datasheet ref. PD-90653F of 28/04/06

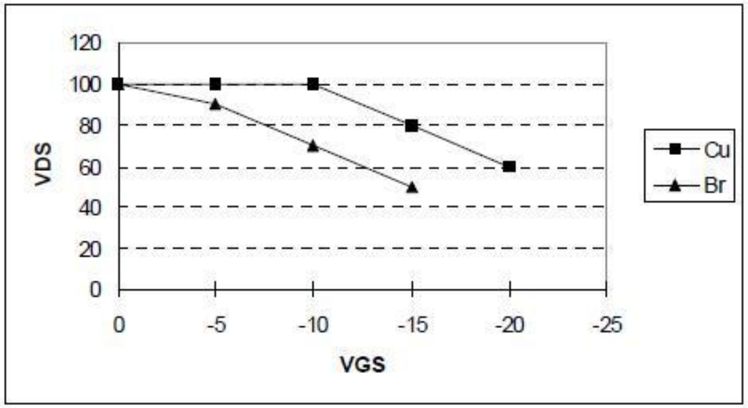


Fig a. Single Event Effect, Safe Operating Area

Qualification System

- ESCC System (European Space Components Coordination)
- QML-V System (Qualified Manufacturer List class V)
- JAN-S System (Joint Army Navy class S)

- ESCC system (European Space Components Coordination)
  - This system is managed by the European Space Agency (ESA) and the national space agencies (CNES, DLR, ASI…)
  - This system is applicable to integrated and discrete devices
  - When the part is qualified, ESA publishes a ”Detail Specification” and introduces the product in the ESCC EPPL/QPL (ESCC European Preferred Part List / Qualified Part List).
  - This specification details the ratings, physical and electrical characteristics and test and inspection data for the component

Qualification System

- QML-V System (Qualified Manufacturer List class V)
    - This system is managed by the Defense Logistics Agency (DLA) Land and Maritime
    - This system is applicable to integrated devices
    - When the part is qualified, the DLA publishes a Standard Microcircuits Drawing (SMD).
    - This document details the physical and electrical characteristics and test and inspection data for the component.

- JAN-S System (Joint Army Navy class S)
    - This system is managed by the Defense Logistics Agency (DLA) Land and Maritime
    - This system is applicable to discrete devices
    - When the part is qualified, the DLA publishes a Performance Specification Sheet (PSS).
    - This document details the physical and electrical characteristics and test and inspection data for the component.

TID Qualification

- To be ESCC, QML-V or JAN-S qualified, no minimum radiation level is required
- If a manufacturer decides to guarantee a TID level on its product, it has to perform TID test according the qualification system
  - ESCC 22900 for the system ESCC
  - MIL-STD-883 TM 1019 for the system QML-V
  - MIL-STD-750 TM 1019 for the system JAN-S

TID Qualification

Lot Qualification

		ESCC	QML-V	JAN-S
		ESCC_22900	MIL-STD-883G,1019.8	MIL-STD-750E,1019.5
irradiation phase	source	60Co or electron accelerator (1 to 3 MeV at die)	60Co	60Co
	Dose rate	Standard: 3.6 to 36 krad/h Low rate: 36 to 360 rad/h	≤ 10mrad/s for Bipolar 50 to 300 rad/s	50 to 300 rad/s
	Dose steps	5 for evaluation testing	Not specified	Not specified
	Parts number	10 + 1 control x 2 for evaluation	Not specified	Not specified
	ELDRS	Specified	Specified	Not specified
	temperature	20°C ± 10°C Δ 3°C	24°C ± 6°C Δ 5°C	24°C ± 6°C Δ 5°C
	Bias	Worst case Evaluation	Worst case	Worst case
post irradiation phase	Room temperature	24 h	< D/Rmax	< D/Rmax
	Over test	1.5 x D level	1.5 x D level	1.5 x D level
	Accelerated annealing	168h at 100°C	168h at 100°C	168h at 100°C
	Bias	Worst case	Worst case	Worst case

D = total ionizing dose

Rmax = maximum dose rate

TID Qualification

Evaluation phase

	ESCC	QML-V	JAN-S
	ESCC_22900	MIL-STD-883G,1019.8	MIL-STD-750E,1019.5
Dose rate	Standard: 3.6 to 36 krad/h Low rate: 36 to 360 rad/h	≤ 10mrad/s for Bipolar 50 to 300 rad/s	50 to 300 rad/s
ELDRS	Specified	Specified	Not specified

- In the case of bipolar or mixed technology/products
  - 10 parts minimum irradiated at low dose rate (≤ 10 mrad/s)
  - 10 parts minimum irradiated at high dose rate (between 50 and 300 rad/s)

- If the measurements for both dose rates are within the initial specifications
  - ELDRS free

- If drift LOW DOSE RATE ≤ 1.5 x drift HIGH DOSE RATE
  - ELDRS free

- When a device is considered as ELDRS free, the next irradiations that will be done by the manufacturer on the production lots will be done at high dose rate only

TID Qualification

Evaluation phase

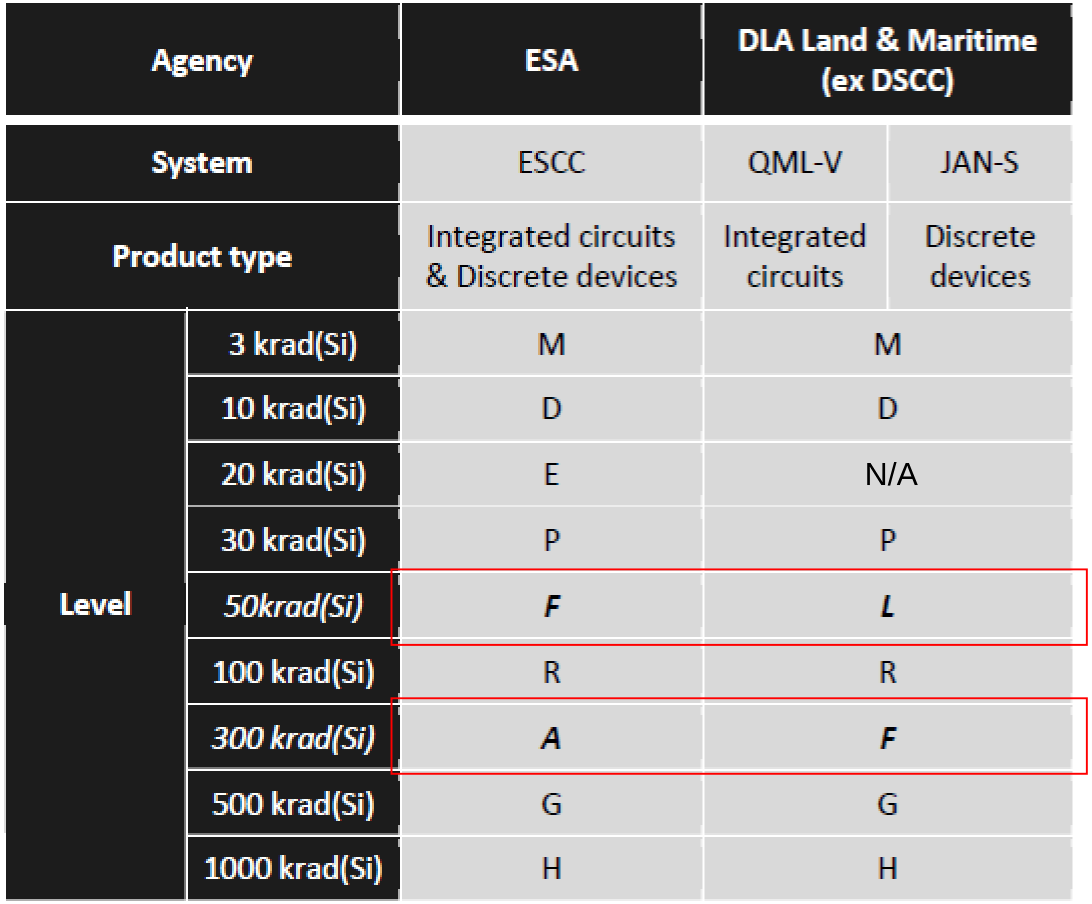
	ESCC	QML-V	JAN-S
	ESCC_22900	MIL-STD-883G,1019.8	MIL-STD-750E,1019.5
Dose rate	Standard: 3.6 to 36 krad/h Low rate: 36 to 360 rad/h	≤ 10mrad/s for Bipolar 50 to 300 rad/s	50 to 300 rad/s
ELDRS	Specified	Specified	Not specified

- RNC-CNES-Q-ST-60-106: SPACE PRODUCT ASSURANCE RADIATION HARDNESS ASSURANCE REQUIREMENTS:
  - « Low Dose Rate is defined as in ESA/SCC 22900 with dose rate being in low dose rate window for devices using bipolar or biCMOS technology (36 to 360 rad(Si)/h) »

- ESA-TEC-QE/2009/22-Rev1 Radiation Hardness Assurance
  - « Devices that contain bipolar transistors (e.g. BICMOS) shall be tested at a dose rate of 36 rad/h. NOTE : Analog bipolar parts are potentially sensitive to ELDRS »

TID Qualification

- When validated by the agencies a specific letter corresponding to the TID level is added in the component number



Agency		**ESA**	**DLA Land & Maritime (ex DSCC)**	
System		ESCC	QML-V	JAN-S
Product type		Integrated circuits & Discrete devices	Integrated circuits	Discrete devices
Level	3 krad(Si)	M	M	
	10 krad(Si)	D	D	
	20 krad(Si)	E	N/A	
	30 krad(Si)	P	P	
	50krad(Si)	***F***	***L***	
	100 krad(Si)	R	R	
	300 krad(Si)	***A***	***F***	
	500 krad(Si)	G	G	
	1000 krad(Si)	H	H	

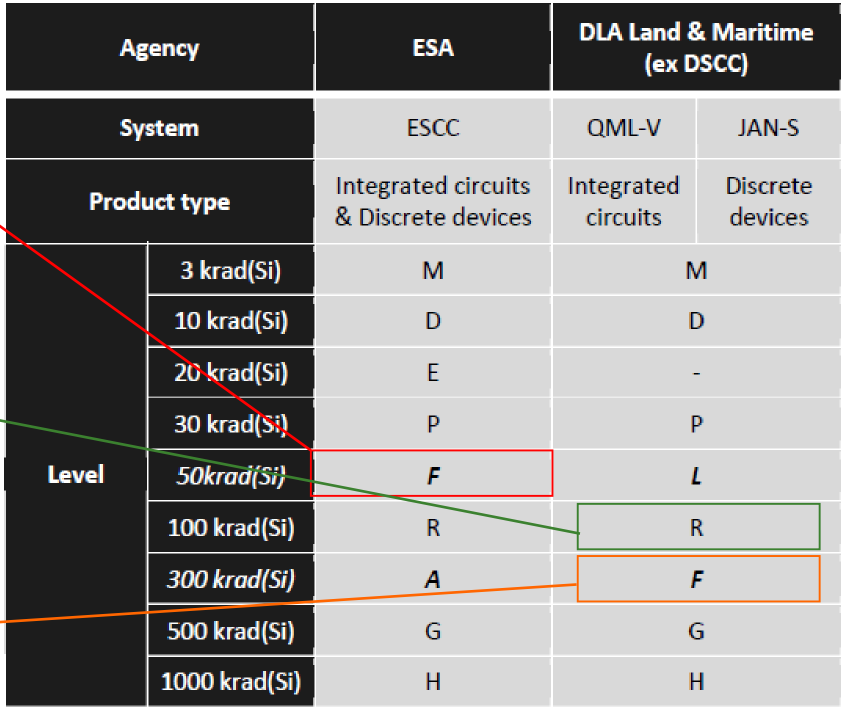
TID Qualification

- In the ESCC system:

  920110501**F** corresponds to the M54HC00K with a TID level of 50krad(Si)

- In the JAN-S system: JS**R**2N2222A corresponds to the 2N2222A with a TID level of 100krad(Si)

- In the QML-V system: 5962**F**0723101VXC corresponds to the RHF330K-01V with a TID level of 300krad(Si),



Agency		ESA	DLA Land & Maritime (ex DSCC)	
System		ESCC	QML-V	JAN-S
Product type		Integrated circuits & Discrete devices	Integrated circuits	Discrete devices
Level	3 krad(Si)	M	M	
	10 krad(Si)	D	D	
	20 krad(Si)	E	-	
	30 krad(Si)	P	P	
	50krad(Si)	***F***	***L***	
	100 krad(Si)	R	R	
	300 krad(Si)	***A***	***F***	
	500 krad(Si)	G	G	
	1000 krad(Si)	H	H	

TID Qualification

- ECSS example qualification

- 9201/105 corresponds to the M54HC00K
  - Datasheet
    - 50 krad QUALIFIED, 100 krad AVAILABLE ON REQUEST
    - NO SEL UNDER HIGH LET HEAVY IONS IRRADIATION
    - DEVICE FULLY COMPLIANT WITH SCC-9201-105
  - https://escies.org/specfamily/view
    - Total Dose Radiation = 50krad

- 9201/041 correspond to the HCC4001B
    - Rad-hard 100 kRad TID at 11rad/sec dose rate
    - SEL-SEU immune to 72 MeV/cm²/mg LET ions
    - ESCC qualified
  - https://escies.org/specfamily/view
    - Total Dose Radiation = NOTHING

TID Qualification

- Acceptance criteria for use of previous TID test reports

- Test report shall comply with the following rules
  - ☐ Test performed in accordance with European ESA/SCC22900 or US MIL-STD 883H 1019.7 total dose test procedures, with low dose rate window for devices using bipolar or biCMOS technology (36 to 360 rad(Si)/h)
  - ☐ The tested parts are manufactured with technology identical (identical process, same mask and identical wafer fab) to the technology to be used for FM (FLYING FLIGHT MODEL) parts (except if technology changes are proven not to alter dose hardness)
  - ☐ Test biasing conditions worst or equivalent to the application
    - ☐ Tested parts from the same diffusion lot than FM parts, whatever date code
    - ☐ OR …

TID Qualification

- Airbus DS method
  - Parts tested date code is not more than 4 years older than the FM parts Date Code (DC) and if the Radiation Design Margin (RDM) methodology is applied

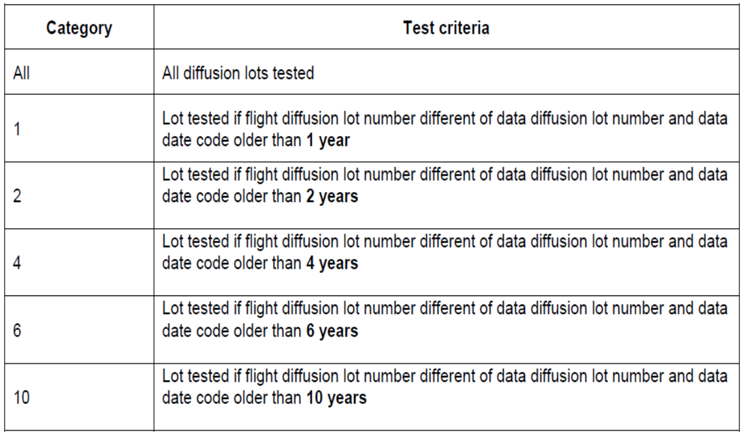
- Comparison between estimated ionizing dose (TIDL Total Ionizing Dose Level) and the sensitivity (TIDS Total Ionizing Dose Sensitivity)
  - TIDL may be estimated by Monte Carlo or Ray-Tracing technique
  - TIDS is determined thanks to manufacturer guarantee, TID ground testing

  - If 2 x TIDL < TIDS ⇨ FM lot is accepted as it is
  - If 1.2 x TIDL < TIDS < 2 x TIDL ⇨ Lot testing (Radiation Verification Testing, RVT).
  - If TIDS < 1.2 x TIDL ⇨ Part not acceptable as is

TID Qualification

- Thales Alenia Space method, if the RADiation Lot Acceptance Test (RADLAT) methodology is applied

	MOS		**BiCMOS - BIPOLAR**		
Device type	**Test criteria[3]**	**Dose rate**	**Test criteria**	**Dose rate**	**Minimum sampling size [4]**
Zener Diodes			10	High or Low	5
Transistors	All	High[1] or Low	2	Low	5
Analog ICs	All	Low[2]	All	Low	5
Logic ICs	1	Low[2]	4	Low	5
ASICs, FPGAs,	All	Low[2]	All	Low	2-5[5]
RAMs, XPROMs,	2	Low[2]	6	Low	2-5[5]
Processors	2	Low[2]	6	Low	2-5[5]
CCD	All	Low[2]	All	Low	2-5[5]
Opto-electronics	All	Low[2]	All	Low	5



Category	Test criteria
All	All diffusion lots tested
1	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than **1 year**
2	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than **2 years**
4	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than **4 years**
6	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than **6 years**
10	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than **10 years**

- 1: For fully MOS technology devices High Dose Rate may be used.
- 2: Low Dose Rate is defined as in ESA/SCC 22900 with dose rate being in low dose rate window for devices using bipolar or biCMOS technology (36 to 360 rad(Si)/h).
- 3: Test criteria (RADLAT test frequency)

- 4: Use of smaller sampling size is subjected to the PROJECT approval. In case of COTS components, sampling size shall never be smaller than 5.
- 5: In case of evaluation a minimum sampling size of 3 shall be required.

TNID Qualification

- If a manufacturer decides to guarantee a TNID level on its product, it has to perform TNID test according the qualification system
    - ESCC 22500 for the system ESCC
    - MIL-STD-883G TM 1017 for the system QML-V
    - MIL-STD-750E TM 1017 for the system JAN-S

		ESCC	QML-V	JAN-S
		ESCC_22500	MIL-STD-883G,1017.2	MIL-STD-750E,1017.1
irradiation phase	source	Electron 2.5MeV Proton (20MeV to 200MeV) Neutron (> 1MeV)	Neutron	Neutron
	Flux	$< 10^9$ particles/cm^2/s	Not specified	Not specified
	Temperature	20°C ± 10°C Δ 3°C	20°C ± 10°C	20°C ± 10°C
	Parts number	5 + 1 control X 2 for evaluation	10+1control	10+1control
	Bias	Worst case Evaluation	Not specified	Not specified

- No specific character is added to the component number referring to the TNID results

TNID Qualification

- Acceptance criteria for use of previous TNID test reports

- Test report shall comply with the following rules
  - Test performed in accordance with norms (ESCC 22500, MIL-STD-883G or MIL-STD-750E TM 1017)
  - The tested parts are manufactured with technology identical (identical process, same mask and identical wafer fab) to the technology to be used for FM (FLYING FLIGHT MODEL) parts (except if technology changes are proven not to alter TNID hardness)
  - Test biasing conditions worst or equivalent to the application
    - Tested parts from the same diffusion lot than FM parts, whatever date code
    - OR …

TNID Qualification

- Airbus DS method
  - Parts tested date code is not more than 4 years older than the FM parts Date Code (DC) and if the RDM (Radiation Design Margin) methodology is applied

- Comparison between estimated non ionizing dose (TNIDL Total Non Ionizing Dose Level) and the sensitivity (TNIDS Total Non Ionizing Dose Sensitivity)
  - TNIDL may be estimate by Monte Carlo or Ray-Tracing technique
  - TNIDS is determined thanks to manufacturer guarantee, TID ground testing

  - If 2 x TNIDL < TNIDS ⇨ FM lot is accepted as it is
  - If 1.2 x TNIDL < TNIDS < 2 x TNIDL ⇨ Lot testing (Radiation Verification Testing, RVT).
  - If TNIDS < 1.2 x TNIDL ⇨ Part not acceptable as is

TNID Qualification

- Thales Alenia Space method, if the RADiation Lot Acceptance Test (RADLAT) methodology is applied

Family	Test Criteria [1]	Sampling
CCD	ALL(*)	2-5[1]
OPTOCOUPLERS	ALL(*)	5
ASIC & LINEAR ICcs (BIPOLAR-BICMOS)	ALL(*) [2]	5
BJT	ALL(*) [2]	5
ZENER DIODES	4 [2]	5
LOW LEAKAGE CURRENT DIODE	4 [2]	5
REFERENCE VOLTAGE DIODE	4 [2]	5

- 1: In case of evaluation a minimum sampling size of 3 devices shall be required.
- 2: Only for mission equivalent 50 MeV proton fluence ≥ $2x10^{11}$ p/cm2

SEE Qualification

- If a manufacturer decides to guarantee a SEE level on its product, it has to perform SEE test according the qualification system:
  - ESCC 25100 for the system ESCC
  - ASTM F-1192 for the system QML-V
  - MIL-STD-750 TM 1080 (SEB/GR for Power MOSFET) for the system JAN-S
  - JESD57

- No specific character is added to the component number referring to the SEE results

LET and Energy	The cross section curves are plotted as function of LET (HI) or energy (P). Therefore the accuracy of the beam is a critical parameter.
Range of particle	A minimum range is specified to ensure the particle LET is constant over the sensitive region and account for cases where long collection distance are involved (SEL, SET, SEB, SEGR.)
Flux uniformity and level	The flux must be homogeneous over the entire die surface to ensure that each part of the device is equally exposed.
Counting	Counting directly affects the cross section calculation. SEL and SEFI introduce dead time periods during which no event can be detected (reset, power cycling ...). It is therefore important to account for these periods when calculating the cross section.

SEE Qualification

Tilt angle	The standards recommend to use normal beam incidence for SET, SEB, SEGR and SEL testing. Proton testing is also performed with normal beam exposures
Maximum LET	If no event is observed at 60 MeV.cm^2/mg, one can conclude that the device is non sensitive
Sample size	The objective is to ensure statistical significance of data. 3 DUT is usually specified but the number of samples must be adapted according to the event type and sensitivity of the devices (destructive events…).
Target fluence	Proton: 10^{10} protons/cm^2 Heavy ion: 10^6 ions/cm^2 for non destructive events (SEU/SET) 10^7 ions/cm^2 for destructive events (SEL) 3. 10^5 ions/cm^2 for SEB/SEGR
Temperature	An elevated temperature reduces device SEL resistance as both saturation cross section and threshold values are affected (some devices not exhibiting SEL at room temperature may be sensitive at elevated temperature). An increase in temperature leads to a lower SEB sensitivity ⇨ Devices have to be tested at operating temperature
Electrical bias condition	A lower bias increase SEU sensitivity A higher bias increase the SEL sensitivity ⇨ It is advised to use the maximum of the specified operating range when testing
Test Condition	Test configuration has to be representative of the final system operating conditions.

SEE Qualification

	ESCC		QML-V	JAN-S
	ESCC_25100	**JEDEC / JESD57**	**ASTM F 11-92**	**MIL-STD-750 1080**
Effect	All	All	All	SEB/SEGR
Radiation sources and characteristics	Heavy ion (range>30µm, 10^2>Flux>10^5ions/cm^2.s) •Proton (20-300 MeV, 10^5>Flux>10^8 protons/cm^2.s)	Heavy ion (applicable to proton neutron or other light particule) •range large compared to the depth of the collection region, 10^2>Flux>10^5ions/cm^2.s	Heavy ion (range>20µm,, 10^2>Flux>10^5ions/cm^2.s	Heavy ion (applicable to proton neutron or other light particule) •range large compared to the depth of the collection region •Flux ≈ 10^5ions/cm^2.s
Dosimetry	Uniformity ± 10% over the device area •Flux ± 10%	Energy ± 10% •Uniformity ± 10% over the device area •Flux ± 10%	Uniformity ± 10% over the device area	Not specified
Testing requirements	Sample size >3 (same Date Code) •5 measurements at different effective LETs [1] (HI) or Energy (p, normal incidence) •Maximum fluence of respectively 10^7 and 10^{10} particule/cm^2.s for HI and P or a meaningful number of events.	Sample size : not specified[2] •Measurement [1,3] at onset threshold , 10%, 25%, 50% and 75-80% of the saturated cross section [5] •Maximum fluence of 10^7 ion/cm^2.s for destructive events (SEL)[6], 10^6 ions/cm^2.s for non destructive events (SEU, SET..) or 100 events.	Sample size : 4 •Maximum fluence of 10^7 ion/cm^2.s or 100 events.	Typical fluence between 10^5 and 10^7 ion/cm^2.

SEE Qualification

	ESCC		QML-V	JAN-S
	ESCC_25100	JEDEC / JESD57	ASTM F 11-92	MIL-STD-750 1080
Effect	All	All	All	SEB/SEGR
Temperature	Room temperature	Not specified	25°C pour SEU/SET •Max temperature ± 10°C for SEL	Room temperature
Operating conditions	Not specified	SEGR [6]: irradiation starts at V_{DS}=0 and increasing in 0.1V increments until gate rupture occurs. •SEU: min operating voltage (WC) •SEL: max operating voltage (WC)	SEU: min operating voltage (WC) •SEL: max operating voltage (WC)	SEGR[6]: irradiation starts at V_{DS}=0 •maximum VDS bias increment ≤ 10 % of the device's rated drain voltage •maximum VGS bias increment ≤ 25 % of the device's rated gate voltage.

•1 The different LET measurements are obtained by several combinations of ion species/energy/angle. The JEDEC document recommends having overlapping data to avoid problems when the cosΘ law is breaking and not to use titled beams when testing for SEB and SEGR.

•2 Device to device variability must be checked

•3 It is advised to repeat 2 or 3 times each run to establish test repeatability or to verify beam stability

•5 Limiting cross section must be checked at the 2 x LET value required for the cross section to saturate or at least at 60 MeV/cm².s

•6 This test is destructive. The final goal is to establish safe operation limits. The device response will be characterized as a function of VDS and LET. JESD57 SEB/SEGR testing of power MOSFET shall be performed in conformance to MIL STD 750E_1080. A part shall be considered as SEB/SEGR free if no event is observed at equivalent LET>60 MeV.cm²/mg, up to a fluence of 3.10^5 ions/cm².

SEE Qualification

- Acceptance criteria for use of previous Single Event Effect (SEE) test reports

- The test report shall comply with the following rules
  - ❑ Test to be performed in accordance with norms (ESCC 25100, JESD57 or ASTM F 11-92) with a minimum sample size of 3 irradiated parts
  - ❑ The tested parts are manufactured with technology identical (identical process, same mask and identical wafer fab) to the technology to be used for FM (FLYING FLIGHT MODEL) parts (except if technology changes are proven not to alter SEE hardness)
  - ❑ Test pattern worst or equivalent to the application

- For SEB and SEGR test report, following information are required
  - ❑ Worst Vgs use
  - ❑ Temperature gap
  - ❑ Minimum LET 38 MeV.cm2/mg, with range > compared to the depth of the collection region
  - ❑ Normal incidence used for planar technology, influence of beam incidence has to be studied for other technology (V-groove...) to identify the worst case

Rad-Hard & Rad-Tolerant

- Rad-Hard and Rad-Tolerant nominations do not have a signification for space qualification level
  - ❑ Conventionally : Rad-Hard > Rad-Tolerant > Commercial parts (COTS)

- Rad-Hard and Rad-Tolerant nominations refer to one or several radiation effects on devices, specified by the manufacturer

- Manufacturer guaranty : the manufacturers may declare their parts insensitive to radiation but…
  - ❑ Don’t trust the commercial label and only follow MIL marking
  - ❑ Rad-Hard label does not mean insensitive to all radiation effects (TID, TNID, SEE)
  - ❑ For Rad-Hard parts read the specifications in detail
  - ❑ Rad-Tolerant parts may be warranted by manufacturers thanks to tests performed in their own radiation conditions

- Radiation guarantees offered by the EEE manufacturers may not well address the space radiation conditions

Rad-Hard & Rad-Tolerant

- Commercial devices
  - Process and design limit the radiation hardness
  - No lot radiation controls

  - Typical hardness levels
    - Total dose: 2 to 10 krad
    - SEU LET threshold: 5 $MeV.cm^2.mg^{-1}$
    - SEU error rate: 10^{-5} err/bit-day

- The customer performs radiation testing and assumes all the risk

Rad-Hard & Rad-Tolerant

- Rad-Tolerant parts
  - Design assures rad hardness up to a certain level
  - No lot radiation controls

  - Typical hardness levels
    - Total dose: 20 to 50 krad
    - SEU LET threshold: 20 MeV.cm^2.mg^{-1}
    - SEU error rate: 10^{-7} to 10^{-8} err/bit-day

- SEE free up to a given LET

- Usually tested for functional fail only, risky

Rad-Hard & Rad-Tolerant

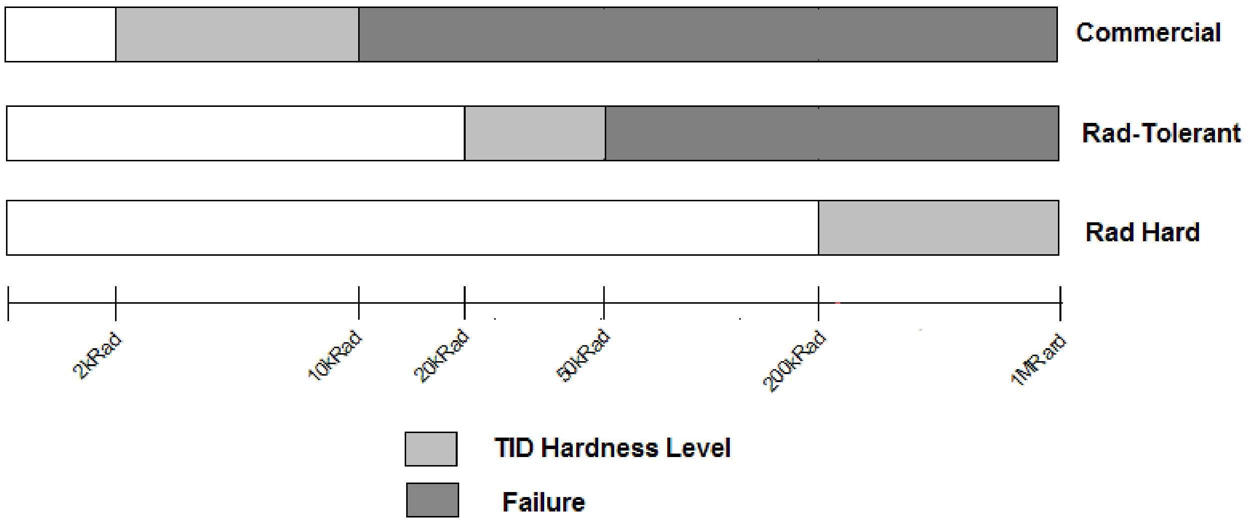
- Rad-Hard parts
  - Designed and processed for particular hardness level
  - Wafer lot radiation tested

- Typical Hardness levels
  - Total dose > 200 krad to >1 Mrad
  - SEU LETth : 80-150 MeV.cm^2.mg^{-1}
  - SEU Error Rate : 10^{-10} to 10^{-12} err/bit-day

- SEE free up to a given LET

Rad-Hard & Rad-Tolerant

- TID typical Level for Commercial, Rad-Hard and Rad-Tolerant devices



Rad-Hard & Rad-Tolerant

- Fall into the trap : ELDRS
  - Enhanced low dose rate sensitivity

- Example of devices claimed as Rad-Hard for TID

intersil®	<u>Intersil Voltage reference IS1009</u> - Rad-Hard guarantee (@ 180 krad/h) ⇨ 300 krad - TID sensitivity (@ 360 rad/h) ⇨ 15 krad
LINEAR TECHNOLOGY	<u>Linear Technology Comparator RH119</u> - Rad-Hard guarantee (@ 180 krad/h) ⇨ 100 krad - TID sensitivity (@ 360 rad/h) ⇨ 11 krad

Rad-Hard & Rad-Tolerant

- Fall into the trap : protons and heavy ion range
  - Penetration depth

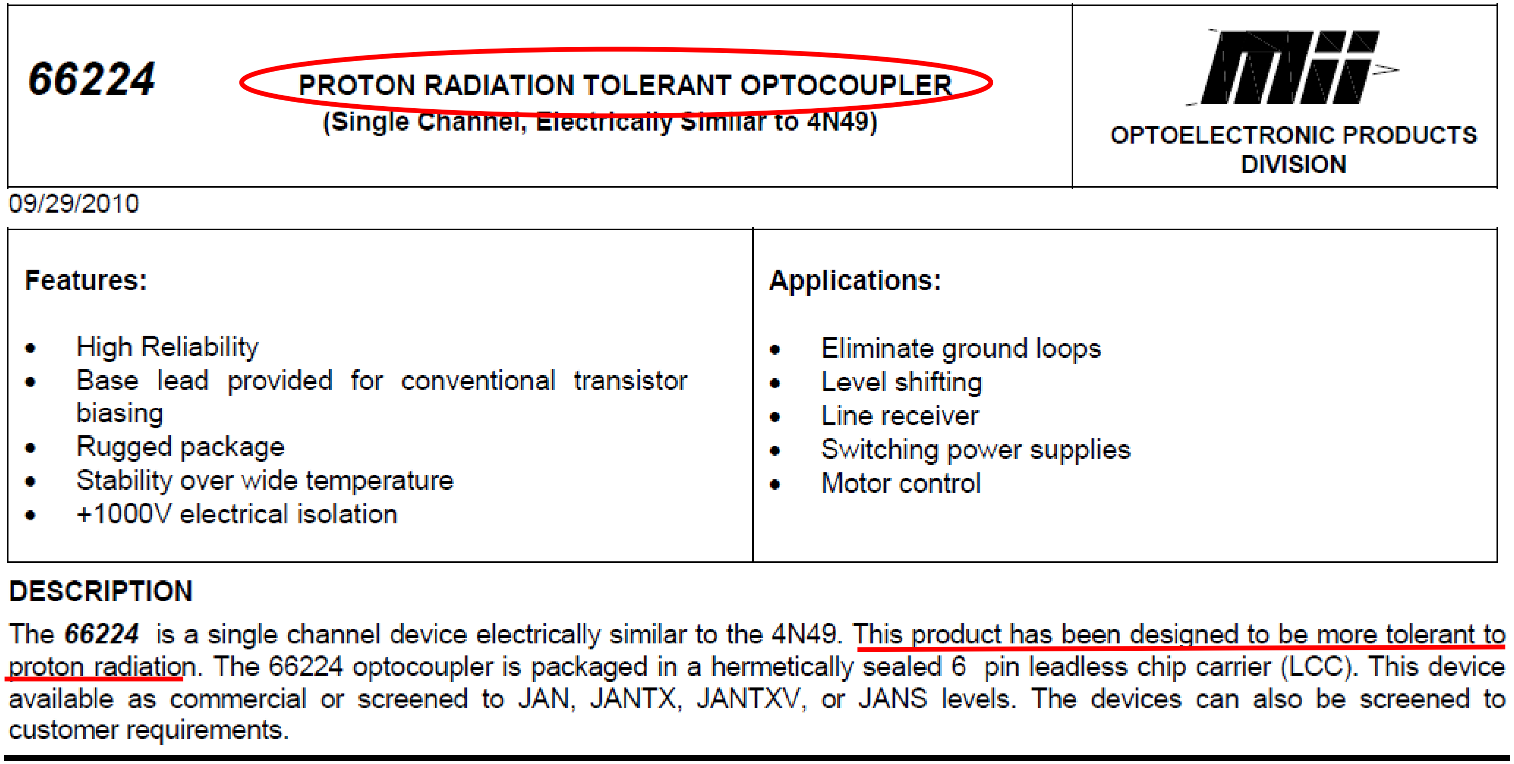
- Example of devices claimed as Rad-Hard for SEE

Honeywell	<u>Honewell memory</u> - Rad-Hard guarantee SEE rate < 10^{-10} SEU/bit/day for GEO mission - SEE Sensitive to proton…
IOR	<u>MOSFET from International Rectifier</u> - Rad-Hard guarantee SOA SEB/SEGR performed at BNL - SEB/SEGR in the SOA tested at TAMU

Rad-Hard & Rad-Tolerant

- Fall into the trap : information missing

- Example of devices claimed as Rad-Tolerant



66224 **PROTON RADIATION TOLERANT OPTOCOUPLER**
(Single Channel, Electrically Similar to 4N49)

OPTOELECTRONIC PRODUCTS DIVISION

09/29/2010

Features:

- High Reliability
- Base lead provided for conventional transistor biasing
- Rugged package
- Stability over wide temperature
- +1000V electrical isolation

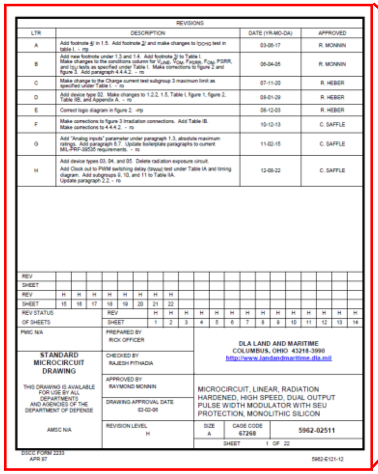
Applications:

- Eliminate ground loops
- Level shifting
- Line receiver
- Switching power supplies
- Motor control

DESCRIPTION

The ***66224*** is a single channel device electrically similar to the 4N49. This product has been designed to be more tolerant to proton radiation. The 66224 optocoupler is packaged in a hermetically sealed 6 pin leadless chip carrier (LCC). This device available as commercial or screened to JAN, JANTX, JANTXV, or JANS levels. The devices can also be screened to customer requirements.

Rad-Hard & Rad-Tolerant



REVISIONS			
LTR	DESCRIPTION	DATE (YR-MO-DA)	APPROVED
A	Add footnote 4/ in 1.5. Add footnote 2/ and make changes to I_{DCHG} test in table I. - rrp	03-06-17	R. MONNIN
B	Add new footnote under 1.3 and 1.4. Add footnote 3/ to Table I. Make changes to the conditions column for V_{LINE}, V_{CM}, F_{PSRR}, F_{CM}, PSRR, and I_{SU} tests as specified under Table I. Make corrections to figure 2 and figure 3. Add paragraph 4.4.4.2. - ro	06-04-05	R. MONNIN
C	Make change to the Charge current test subgroup 3 maximum limit as specified under Table I. - ro	07-11-20	R. HEBER
D	Add device type 02. Make changes to 1.2.2, 1.5, Table I, figure 1, figure 2, Table IIB, and Appendix A. - ro	08-01-29	R. HEBER
E	Correct logic diagram in figure 2. -rrp	08-12-03	R. HEBER
F	Make corrections to figure 3 Irradiation connections. Add Table IB. Make corrections to 4.4.4.2. - ro	10-12-13	C. SAFFLE
G	Add "Analog inputs" parameter under paragraph 1.3, absolute maximum ratings. Add paragraph 6.7. Update boilerplate paragraphs to current MIL-PRF-38535 requirements. - ro	11-02-15	C. SAFFLE
H	Add device types 03, 04, and 05. Delete radiation exposure circuit. Add Clock out to PWM switching delay (t_{PWM}) test under Table IA and timing diagram. Add subgroups 9, 10, and 11 to Table IIA. Update paragraph 2.2. - ro	12-08-22	C. SAFFLE

REV								
SHEET								
REV	H	H	H	H	H	H	H	H
SHEET	15	16	17	18	19	20	21	22

REV STATUS	REV	H	H	H	H	H	H	H	H	H	H	H	H	H	H
OF SHEETS	SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14

PMIC N/A

PREPARED BY
RICK OFFICER

DLA LAND AND MARITIME
COLUMBUS, OHIO 43218-3990
http://www.landandmaritime.dla.mil

STANDARD MICROCIRCUIT DRAWING

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

CHECKED BY
RAJESH PITHADIA

APPROVED BY
RAYMOND MONNIN

DRAWING APPROVAL DATE
02-02-06

MICROCIRCUIT, LINEAR, RADIATION HARDENED, HIGH SPEED, DUAL OUTPUT PULSE WIDTH MODULATOR WITH SEU PROTECTION, MONOLITHIC SILICON

AMSC N/A

REVISION LEVEL
H

SIZE
A

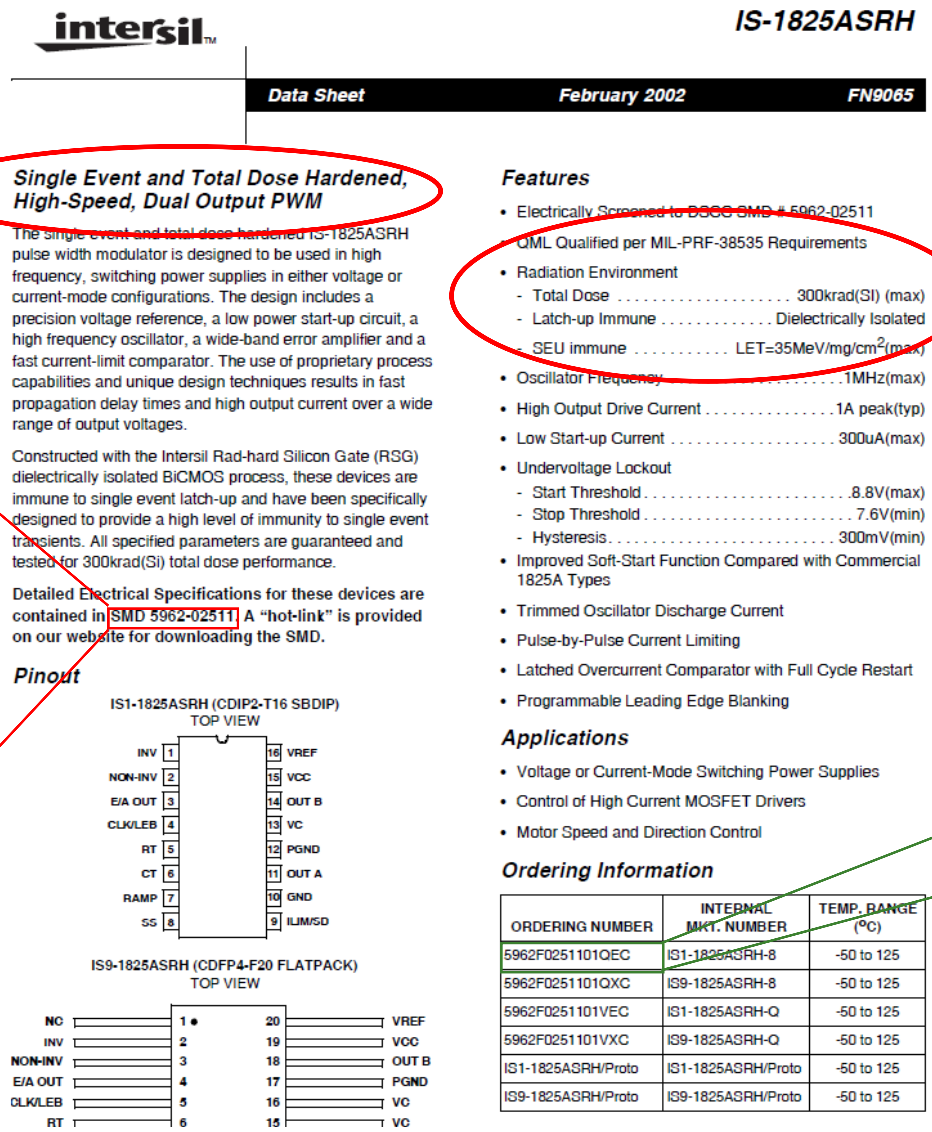
CAGE CODE
67268

5962-02511

SHEET 1 OF 22

DSCC FORM 2233
APR 97

5962-E121-12



intersil

IS-1825ASRH

Data Sheet | **February 2002** | **FN9065**

Single Event and Total Dose Hardened, High-Speed, Dual Output PWM

The single event and total dose hardened IS-1825ASRH pulse width modulator is designed to be used in high frequency, switching power supplies in either voltage or current-mode configurations. The design includes a precision voltage reference, a low power start-up circuit, a high frequency oscillator, a wide-band error amplifier and a fast current-limit comparator. The use of proprietary process capabilities and unique design techniques results in fast propagation delay times and high output current over a wide range of output voltages.

Constructed with the Intersil Rad-hard Silicon Gate (RSG) dielectrically isolated BiCMOS process, these devices are immune to single event latch-up and have been specifically designed to provide a high level of immunity to single event transients. All specified parameters are guaranteed and tested for 300krad(Si) total dose performance.

Detailed Electrical Specifications for these devices are contained in SMD 5962-02511. A "hot-link" is provided on our website for downloading the SMD.

Pinout

IS1-1825ASRH (CDIP2-T16 SBDIP)
TOP VIEW

INV	1	16	VREF
NON-INV	2	15	VCC
E/A OUT	3	14	OUT B
CLK/LEB	4	13	VC
RT	5	12	PGND
CT	6	11	OUT A
RAMP	7	10	GND
SS	8	9	ILIM/SD

IS9-1825ASRH (CDFP4-F20 FLATPACK)
TOP VIEW

NC	1	20	VREF
INV	2	19	VCC
NON-INV	3	18	OUT B
E/A OUT	4	17	PGND
CLK/LEB	5	16	VC
RT	6	15	VC

Features

- Electrically Screened to DSCC SMD # 5962-02511
- QML Qualified per MIL-PRF-38535 Requirements
- Radiation Environment
  - Total Dose . . . . 300krad(SI) (max)
  - Latch-up Immune . . . . Dielectrically Isolated
  - SEU immune . . . . LET=35MeV/mg/cm^2(max)
- Oscillator Frequency . . . . 1MHz(max)
- High Output Drive Current . . . . 1A peak(typ)
- Low Start-up Current . . . . 300uA(max)
- Undervoltage Lockout
  - Start Threshold . . . . 8.8V(max)
  - Stop Threshold . . . . 7.6V(min)
  - Hysteresis. . . . . 300mV(min)
- Improved Soft-Start Function Compared with Commercial 1825A Types
- Trimmed Oscillator Discharge Current
- Pulse-by-Pulse Current Limiting
- Latched Overcurrent Comparator with Full Cycle Restart
- Programmable Leading Edge Blanking

Applications

- Voltage or Current-Mode Switching Power Supplies
- Control of High Current MOSFET Drivers
- Motor Speed and Direction Control

Ordering Information

ORDERING NUMBER	INTERNAL MKT. NUMBER	TEMP. RANGE (^{o}C)
5962F0251101QEC	IS1-1825ASRH-8	-50 to 125
5962F0251101QXC	IS9-1825ASRH-8	-50 to 125
5962F0251101VEC	IS1-1825ASRH-Q	-50 to 125
5962F0251101VXC	IS9-1825ASRH-Q	-50 to 125
IS1-1825ASRH/Proto	IS1-1825ASRH/Proto	-50 to 125
IS9-1825ASRH/Proto	IS9-1825ASRH/Proto	-50 to 125

5962**F**0251101QEC

Conclusion

- There are uncertainties in the radiation engineering aspects on a space project

- Dealing efficiently with these uncertainties is the added value of radiation engineers
  - Environment understanding and computation
  - Calculation of dose, fluence and SEE rate
  - Representativity of tests performed
    - Test method, dose rate…

- The industrial approach consists in
  - Application of generic methodology
  - Application of safety rules (design margins)

- Keeping an eye on literature, and on model and software improvement…