Lot-to-Lot Variability and TID degradation of Bipolar Transistors Analyzed with ESA and PRECEDER Databases

Pedro Martín-Holgado[1], Amor Romero-Maestre[1], José de-Martín-Hernández[2], Florian Krimmel[3], Thomas Borel[3], Michele Muschitiello[3], Alessandra Costantino[3], Ferdinando Tonicello[3], Christian Poivey[3], Anastasia Pesce[3], Olga Ramos[2], Manuel Domínguez[2], and Yolanda Morilla[1]

[1] Centro Nacional de Aceleradores (CNA); [2] Alter Technology TÜV Nord; [3] European Space Agency (ESA)

SMC-IT & SCC 2023 Conference CALTECH | PASADENA, CA

How the use of archival data can help to perform a numerical assessment of the lot-to-lot variability?

I. Abstract

The **NewSpace** era has drastically increased the use of **COTS** (Commercial-Off-The-Shelf components) to cover the needs of the new requirements: lower costs, shorter lead times, and better performances.

The radiation risks associated with non-radiation hardened components are especially relevant. Therefore, new approaches must be considered necessary to address this challenge to ensure the radiation hardness.

This work presents **standard and parameterized radiation databases** and how they can be used to numerically **assess the critical lot-to-lot variability** in response to gamma radiation.

II. Data Sources

The **ESA Radiation Test database** is the largest open-access radiation test report database in Europe, with hundreds of entries to date.
Accessible on the web site: https://esarad.esa.int/

The **PRECEDER database** (developed by CNA and Alter Technology) is the largest database with parameterized information,. with thousands of radiation test results available to be used in new analysis.
Restricted access through the Virtuallab platform:
https://virtuallab.altertechnology.com/

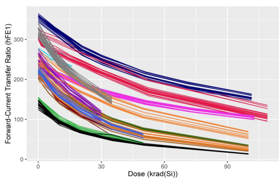
III. Data selection

Forward-current transfer ratio (gain) h_{FE1}
11 BJT part-types - 138 lots / TID @ 36 to 360 rad(Si)/h window

Part type	Quality	#MFRs	#Lots	h_{FE1} Test Conditions
2N2222	Qualified	5	27	V_{CE} = 10 V; I_C = 100 mA
2N2369	Qualified	4	9	V_{CE} = 35 V; I_C = 10 mA
2N2907	Qualified	5	14	V_{CE} = -10 V; I_C = 100 mA
2N2920	Qualified	1	12	V_{CE} = 5 V; I_C = 100 mA
2N3700	Qualified	3	18	V_{CE} = 10 V; I_C = 150 mA
2N3810	Qualified	2	13	V_{CE} = 5 V; I_C = 100 mA
2N5154	Qualified	2	13	V_{CE} = 5 V; I_C = 50 mA
2N5551	Qualified	2	5	V_{CE} = 5 V; I_C = 1 mA
BC817	COTS	3	9	V_{CE} = 1 V; I_C = 0,1 mA
BC847	COTS	3	9	V_{CE} = 1 V; I_C = 0,01 mA
BC857	COTS	3	9	V_{CE} = 1 V; I_C = 0,01 mA

IV. Preliminar Analysis

Using directly **raw data** for several lots, including all pieces can be cluttered!!!



2N3810 BJT h_{FE1} gain results

13 lots from different manufacturers

Each color represents one lot

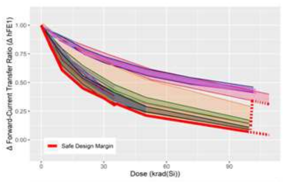
First approach, representing the range of values of all the pieces per lot.
Safe Design Margin Envelope as established by ESA, based on the worst case.

Safe Design Margin applied to 2N3810 BJT
Considering to mitigate the degradation risk

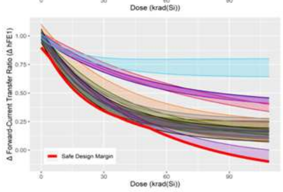
EVIDENCE of dependence on radiation steps and the total dose achieve

DRAWBACK to assess lot-to-lot variability

SOLUTION using the best-fit curve for each lot

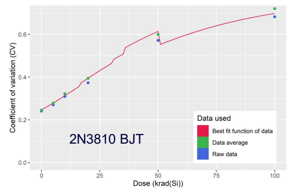


Normalized gain degradation and **SDM** applied using the **best-fit curve** by PRECEDER methodology.



V. Lot-to-Lot Variability

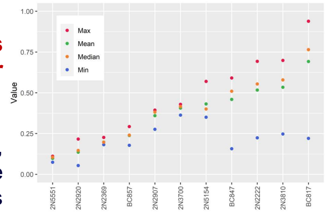
Coefficient of Variation, ratio of the standard deviation to the mean: $CV = \frac{s}{\bar{x}}$

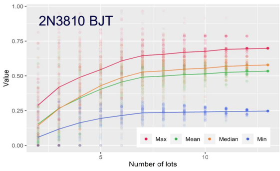


Equivalent statistics results found, considering the gain measured for all irradiated pieces at each irradiation step (raw data), the mean of these values (data average), or the best fit function curve.

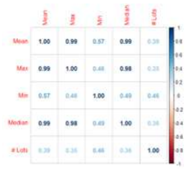
COTS present CVs in the same range as qualified parts for the analyzed bipolar transistors.

Coefficient of variation (máximum, mean, median, and minimum) calculated using the best-fit function, for all the studied part types
.





No significant correlation has been detected between the **number of lots** and the **CV value**.



A **saturation phenomenon** has been observed after representing the CV calculated for different sampling sizes, from two lots up to the total number, randomly selecting lots up to 100 iterations

VI. Conclusions

The collection of radiation test results, such as **ESA and PRECEDER databases,** allows a **comparative analysis** of the response to radiation.

The **coefficient of variation** is an excellent candidate to compare different lots and references because it is dimensionless.

This methodology proposes a **quantitative analysis of historical data** to numerically evaluate the lot-to-lot variability of devices.

The lot-to-lot variability of bipolar transistors under gamma radiation do not seem to depend on the accumulated dose and the qualification process.

The authors **recommend not to generalize these statements** to other part types and families without providing stronger evidence.

ALTER — CNA Centro Nacional de Aceleradores — ICTS Infraestructuras Científicas y Técnicas Singulares — esa