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TID versus ELDRS on Transistors The Whole Picture

Microsemi Space Forum 2015

Ray DiBugnara
Director of Technology and Radiation Services

Microsemi SPACE FORUM

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Metrics

Measuring the Radiation Response

BJT: Example on Calculating "Bracket" [hFE]

Bipolar Transistors:
A special designation has been developed as a measure of the gain drop across irradiation. It is meant to create a value that not only monitors the total drop in gain but also the relative drop in gain vs. the final test requirement:

Calculating $[h_{FE}]$:

$\Delta(1/h_{FE}) = 1/h_{FE}2 - 1/h_{FE}1$

$h_{FE}1$ = initial test reading for h_{FE}
$h_{FE}2$ = test reading after exposure

$[h_{FE}] = 1/((\Delta(1/h_{FE}) + 1/h_{FE}\ min))$

h_{FE} min = Slash Sheet min specification

Example:

$h_{FE}1 = 200$, $h_{FE}2 = 125$, $h_{FE}\ min = 100$

$\Delta(1/h_{FE}) = 1/125 - 1/200$
$= 0.008 - 0.005 = 0.003$

$[h_{FE}] = 1/(0.003 + 1/100)$

$= 1/(0.003 + 0.010) = 1/.013 =$ **76.9**

By definition, always lower than h_{FE} min.
Note: You can always find $\Delta(1/h_{FE})$ again.

(Ref: Mil-Std-750 Test Method 1019.6 Para 3.12)

BJT: Calculating Normalized Delta(1/hFE)

Calculating: Δ (1/h_{FE}):

Δ(1/h_{FE}) = 1/h_{FE}2 – 1/h_{FE}1

This is invaluable for interpolating and extrapolating the Gamma radiation response of a BJT and folding in displacement damage exposure, but...

Problem:

Cannot compare individual parts within a lot or across various technologies if the gain varies from sample to sample.

Solution:

Calculating Normalized Δ (1/h_{FE}) :

Normalized Δ (1/h_{FE}) =

1/(h_{FE}2/h_{FE}1) – 1/(h_{FE}1/h_{FE}1) =

1/(h_{FE}2/h_{FE}1) – 1

Example:

BJT#1 h_{FE}1 = 50 , h_{FE}2 = 25

Δ (1/h_{FE}) = 1/25 – 1/50 = **0.02**

BJT#2 h_{FE}1 = 300 , h_{FE}2 = 150

Δ (1/h_{FE}) = 1/150 – 1/300 = **0.003**

Both were affected the same yet you cannot tell from the Δ(1/h_{FE}) values.

Now Normalized (N):

BJT#1 h_{FE}1 = 50 , h_{FE}2 = 25

NΔ (1/h_{FE}) = 1/(25/50) –1 = **1.0**

BJT#2 h_{FE}1 = 300 , h_{FE}2 = 150

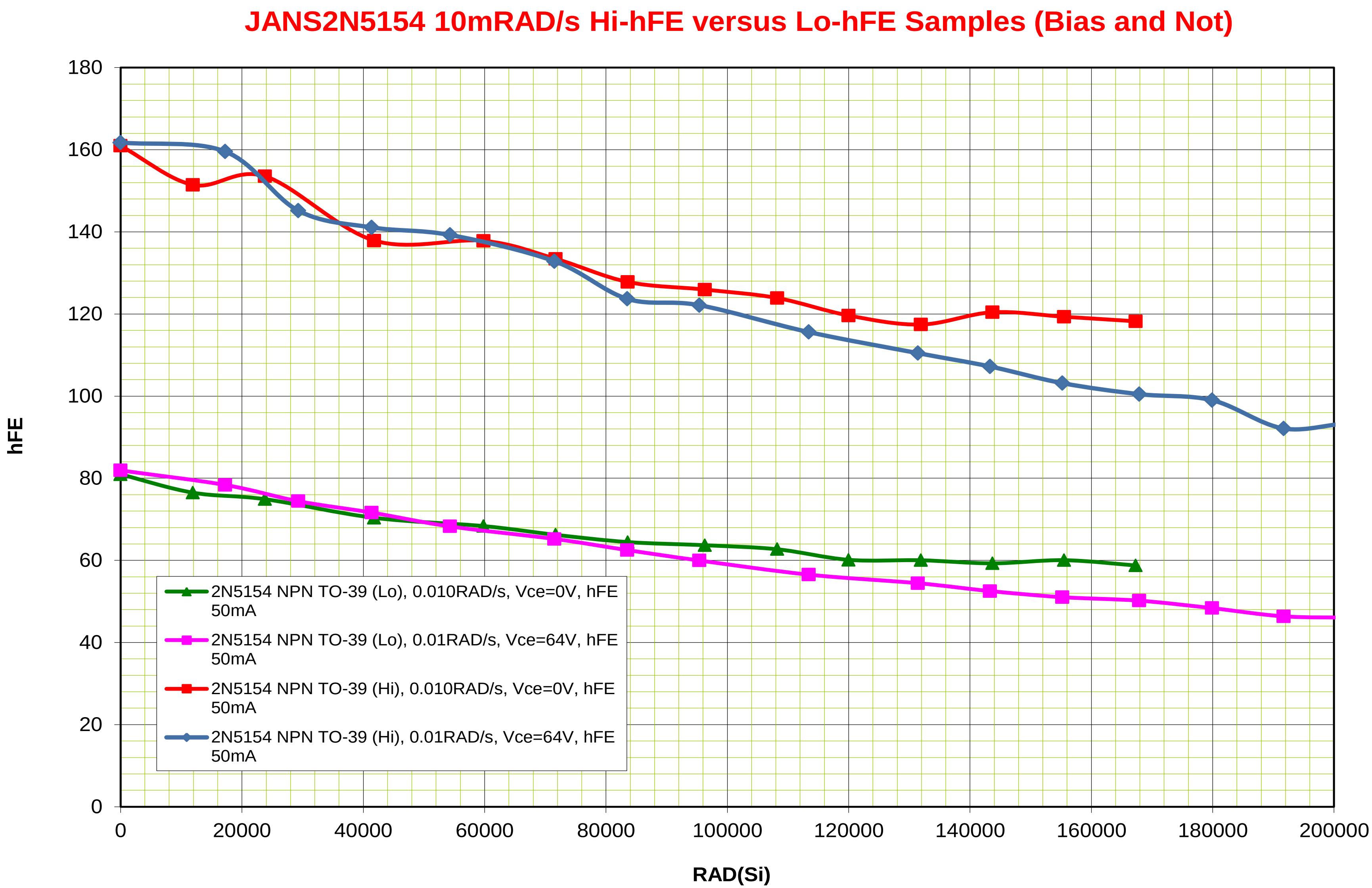
NΔ (1/h_{FE}) = 1/(150/300) –1 = **1.0**

Now can compare plus plot on the same scale.

Common Ground for RAD Comparison

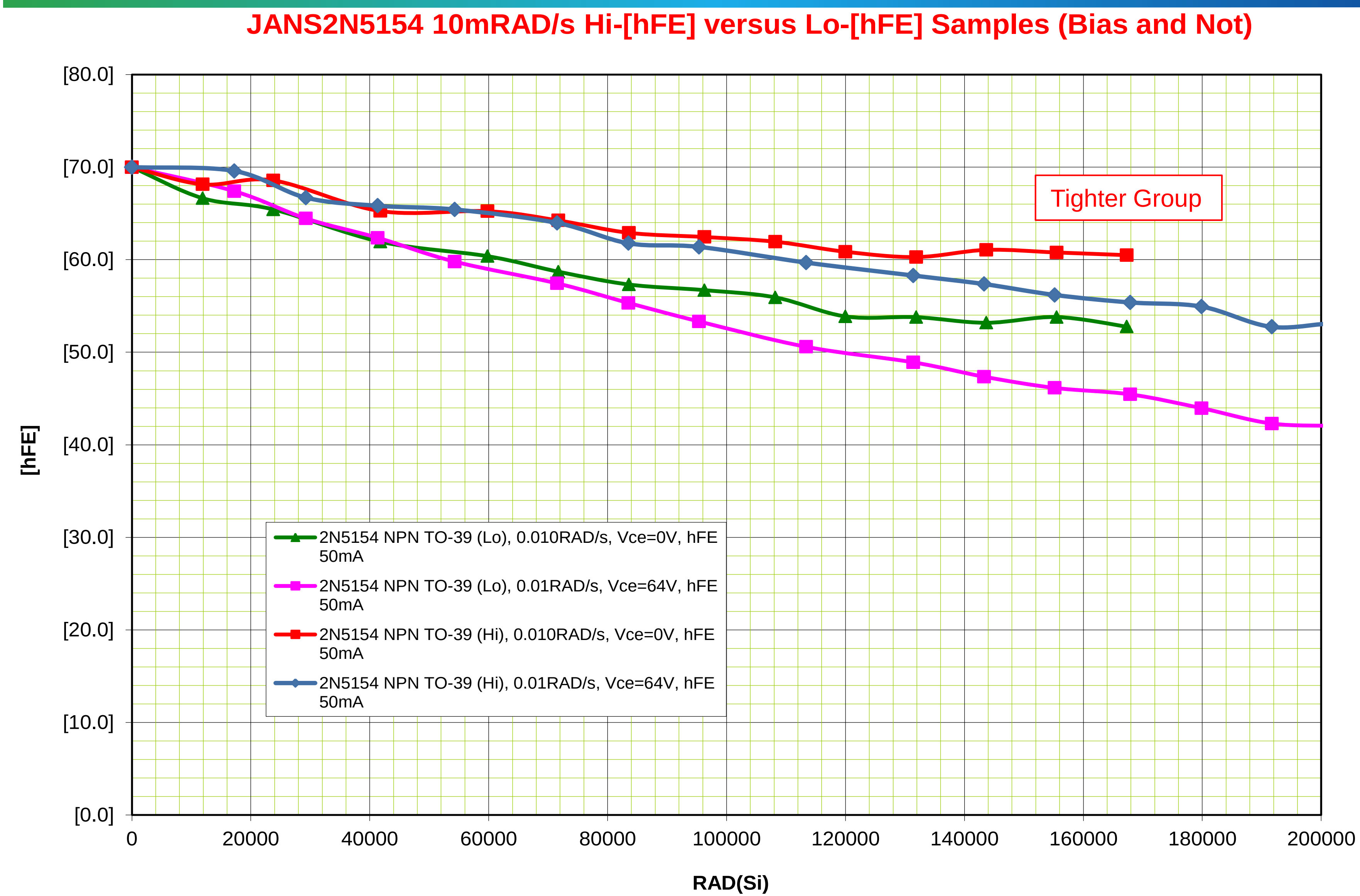
Difficulty with hFE Comparison

From Same Lot but Different Initial hFE Values (All In Spec by the Way)



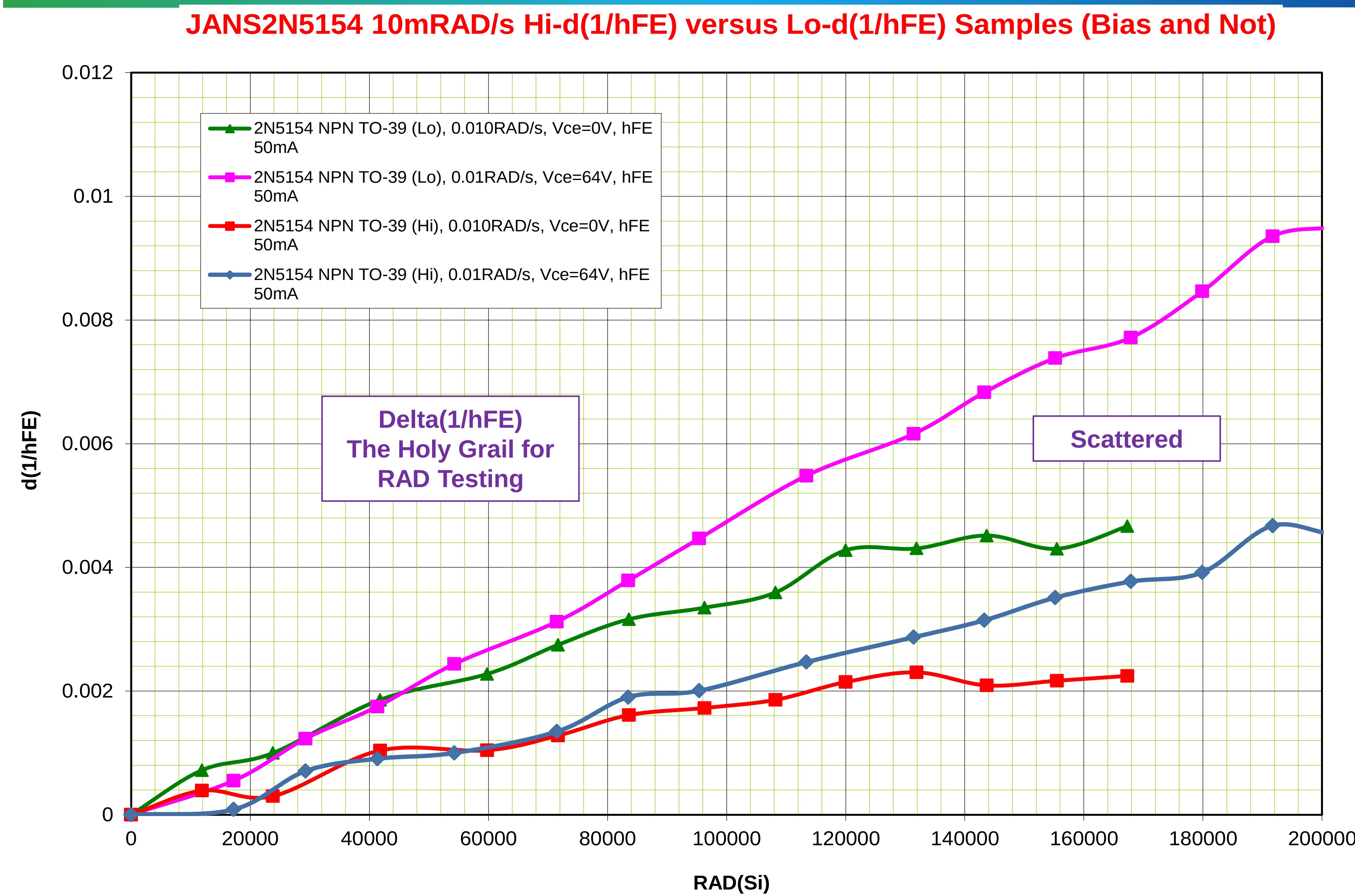
Use of [hFE] Comparison Helps

From Same Lot but Different Initial hFE Values (All In Spec)



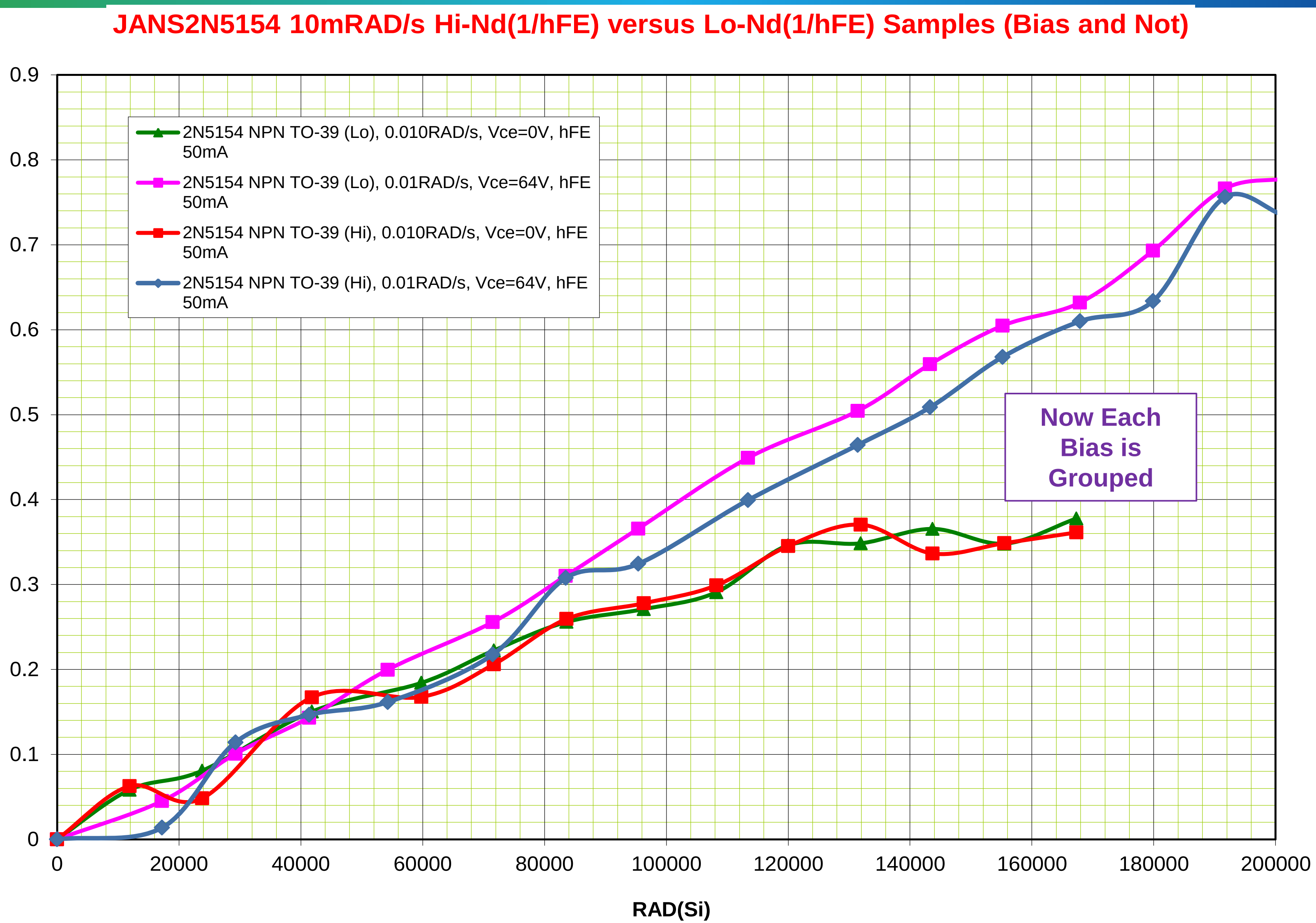
Difficulty with Delta(1/hFE) Comparison

From Same Lot but Different Initial hFE Values (All In Spec)



Normalized Delta(1/hFE) Really Helps

Similarity of the Technology is More Apparent



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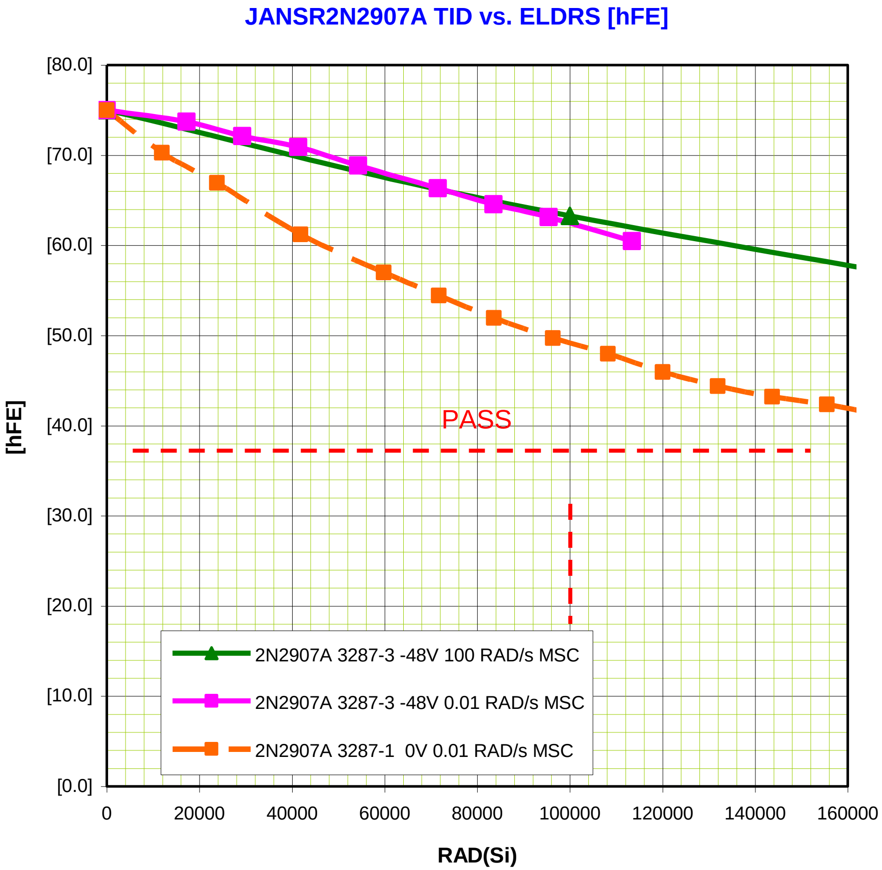
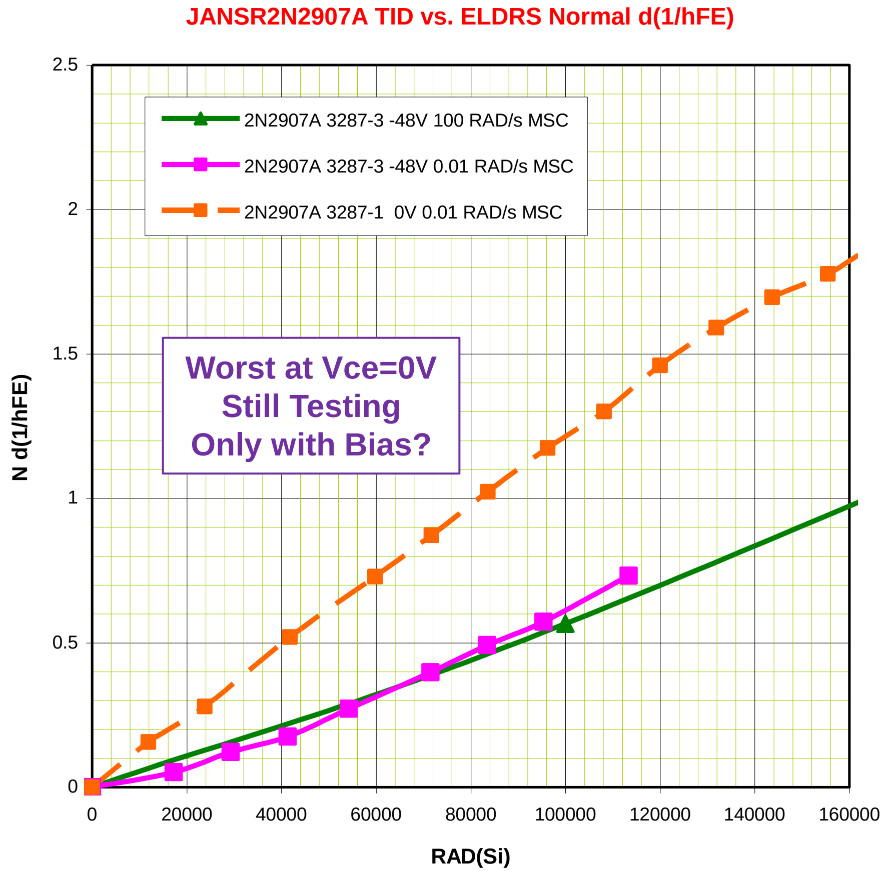
PNP Transistors TID vs. ELDRS

JANSR2N2907A TO-18 Lot 3287 W3, L2.0

PNP 60V With Added Vce=0V ELDRS Data (Not a Group D Requirement)





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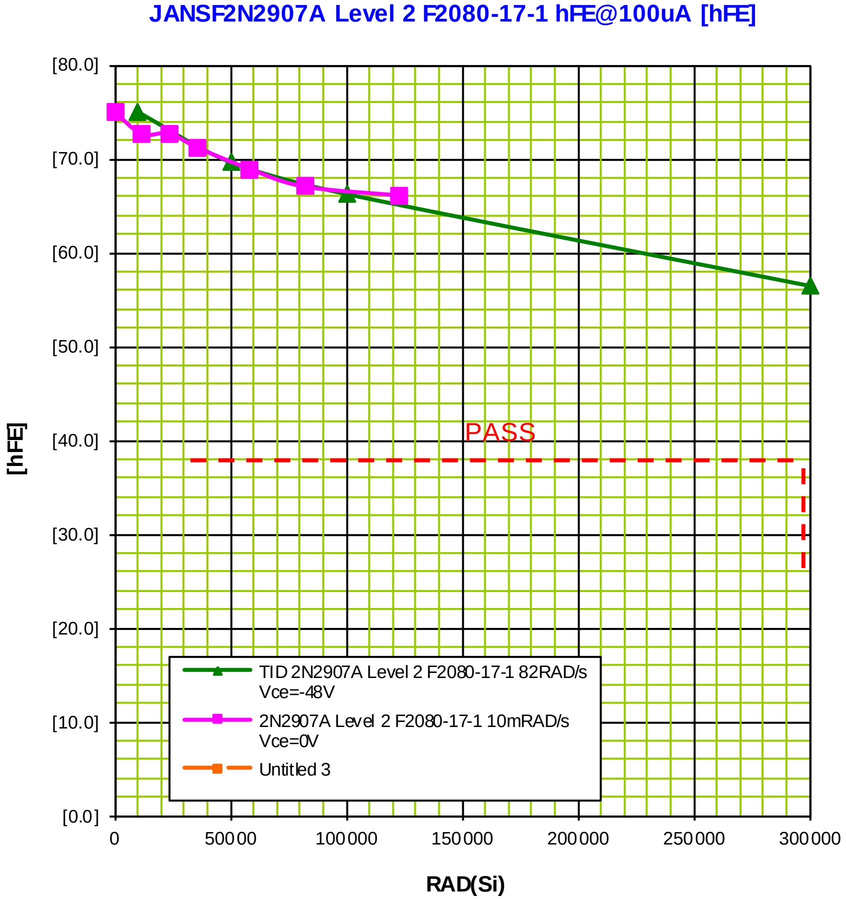
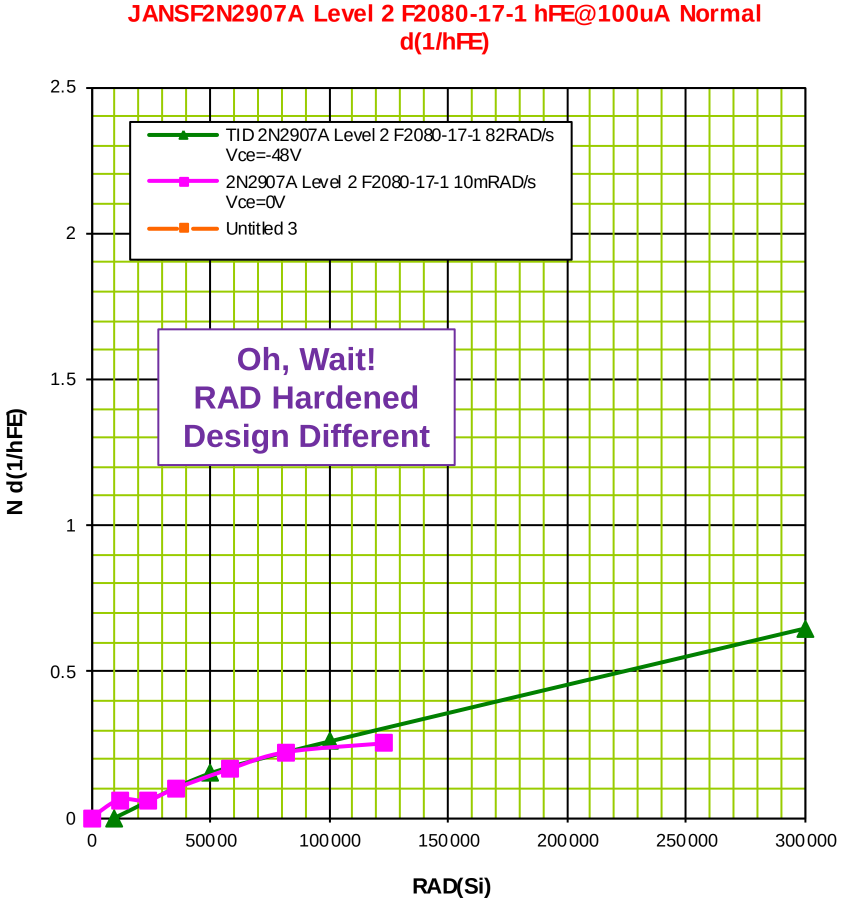
The value of delta(1/hFE) is frequently used as a tool for predicting how well a Bipolar transistor will perform beyond the radiation exposure used for the data. However, it can only be used to compare individual transistors when they start with the same hFE value. A Normalized delta(1/hFE) permits comparisons even when the starting hFE varies from part to part.

JANSF2N2907A TO-18 Lot F2080 W17, L2.0

PNP 60V New RAD-Hard Design





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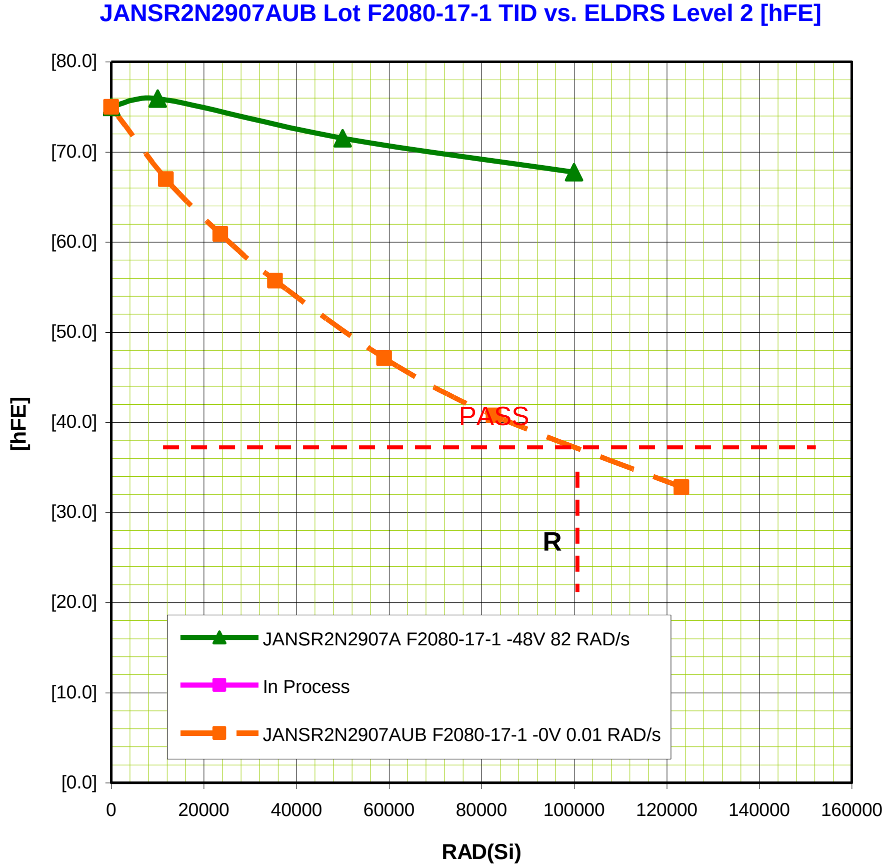
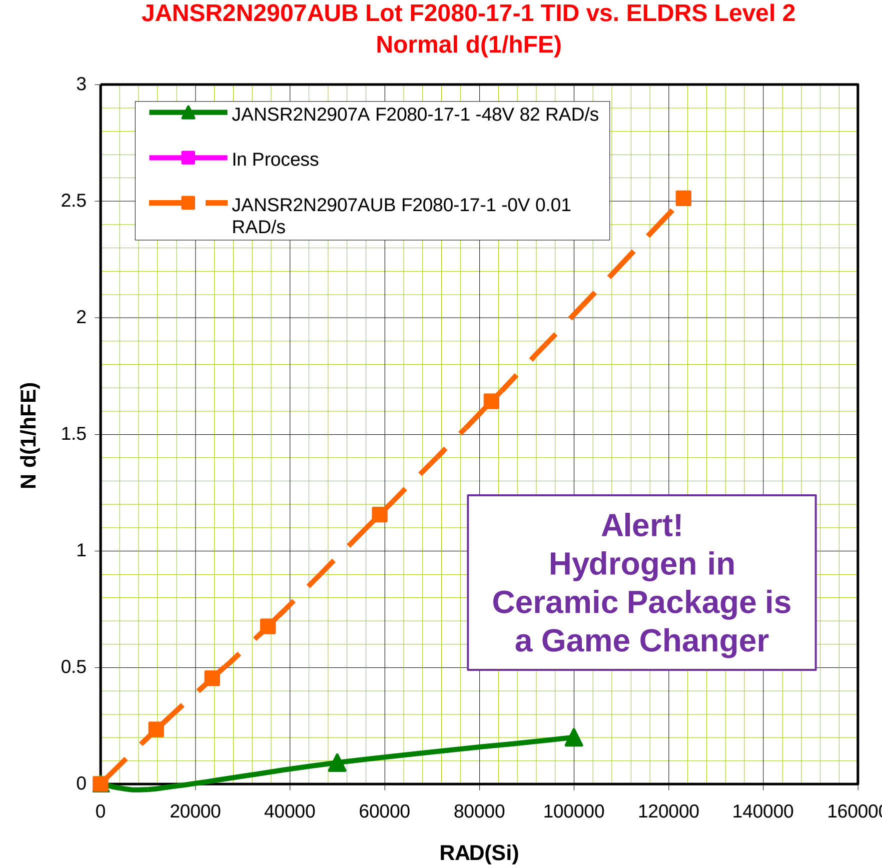
JANSR2N2907AUB Lot Z2080 W17, L2.0

PNP 60V Mitigating UB Package Outgas Phenomenon





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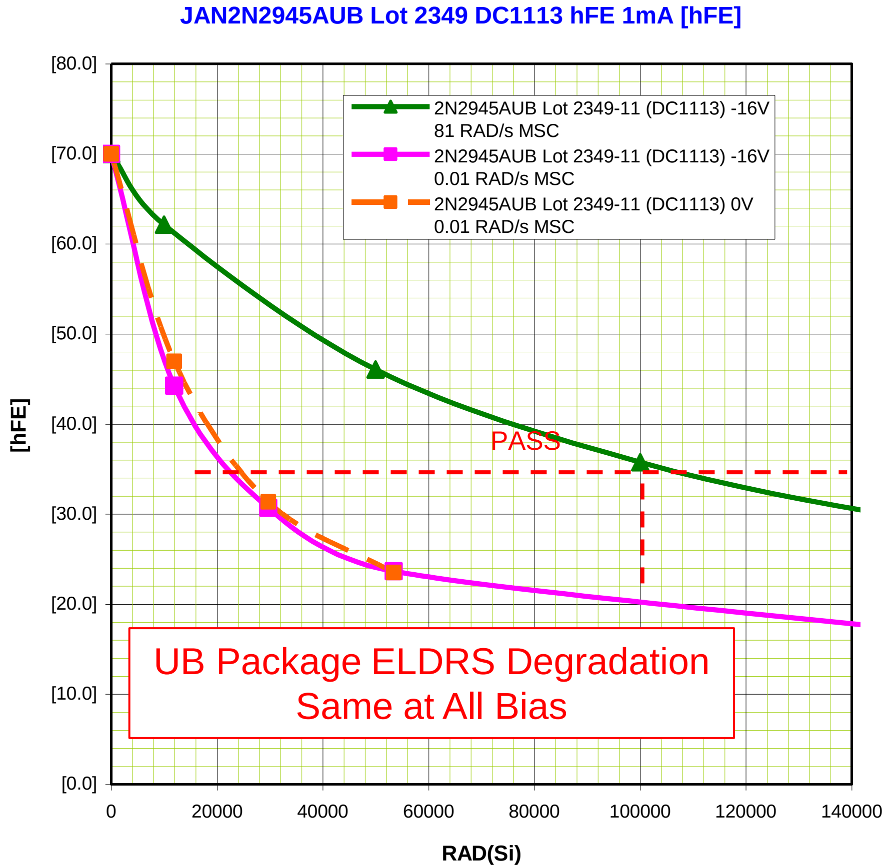
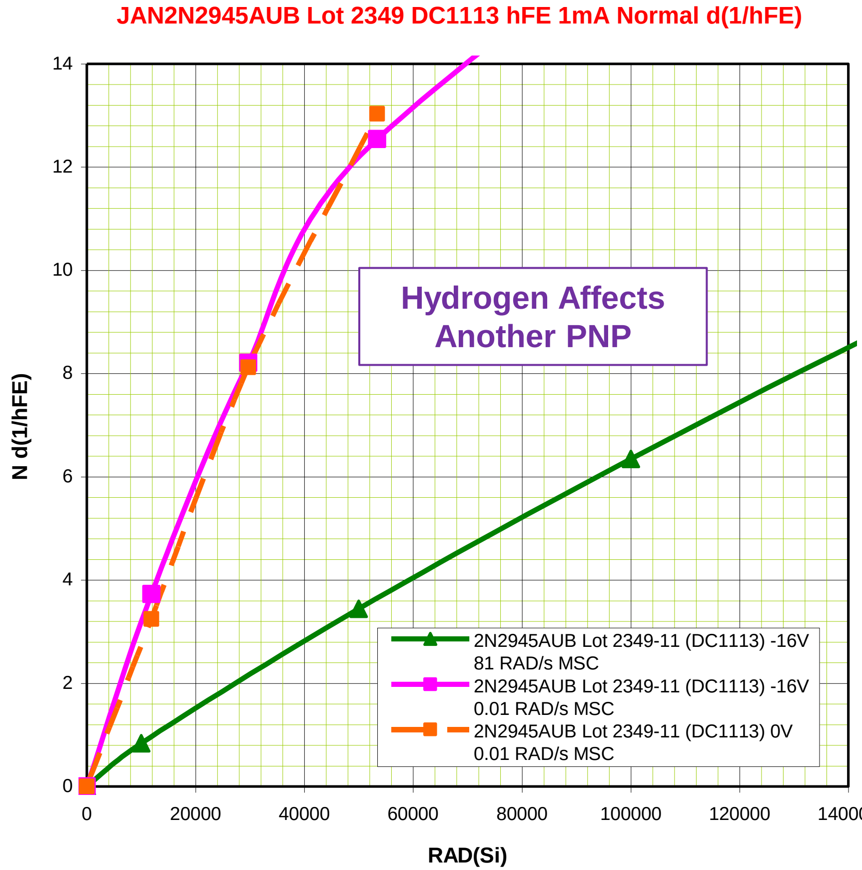
JAN2N2945AUB Lot 2349 W11, L0.0M (DC1113)

PNP 20V With Added Vce=0V ELDRS Data





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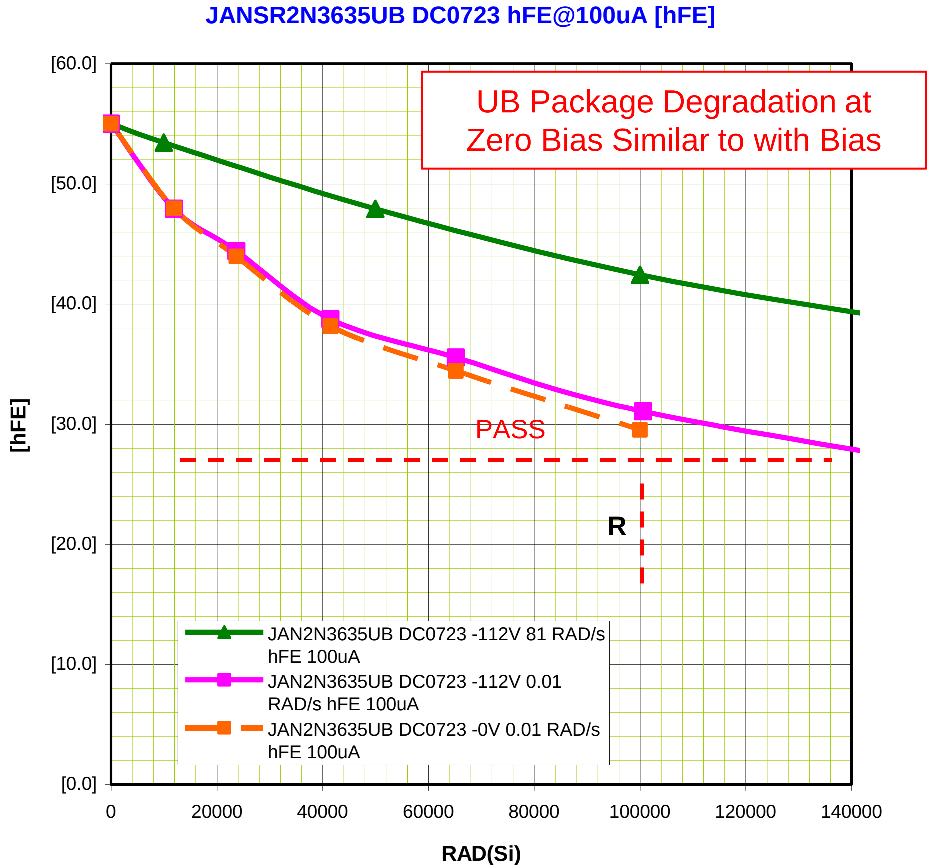
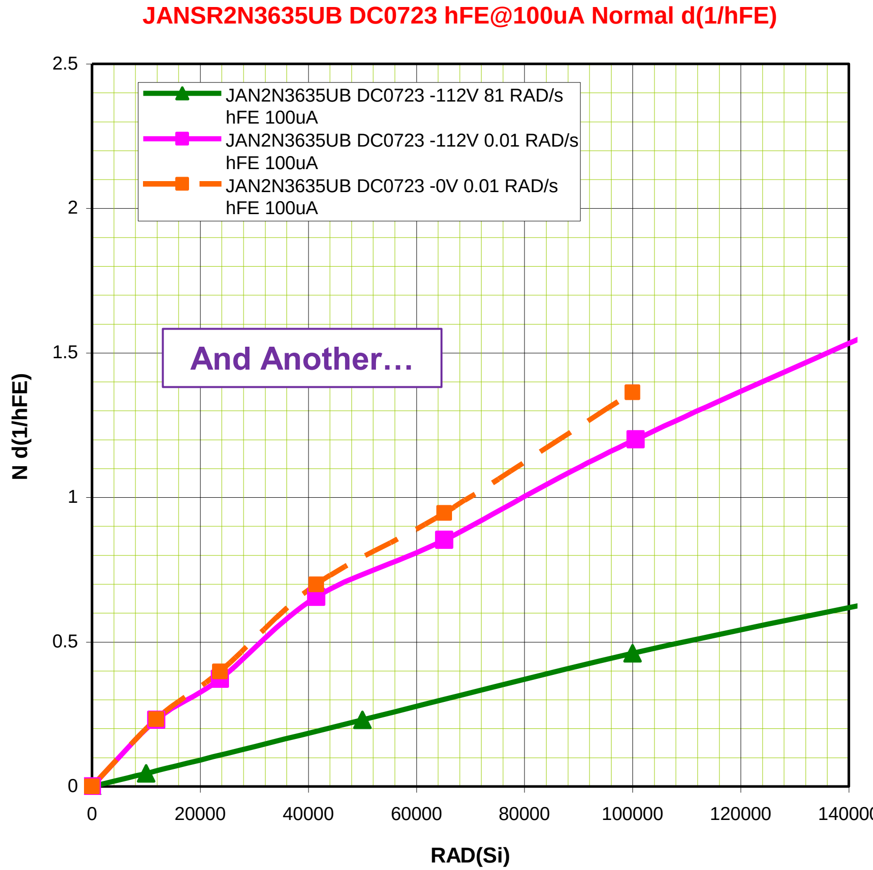
JANSR2N3635UB L0.0P DC0723

PNP 140V With Added Wafer Vce=0V ELDRS Data (Not a Group D Requirement)





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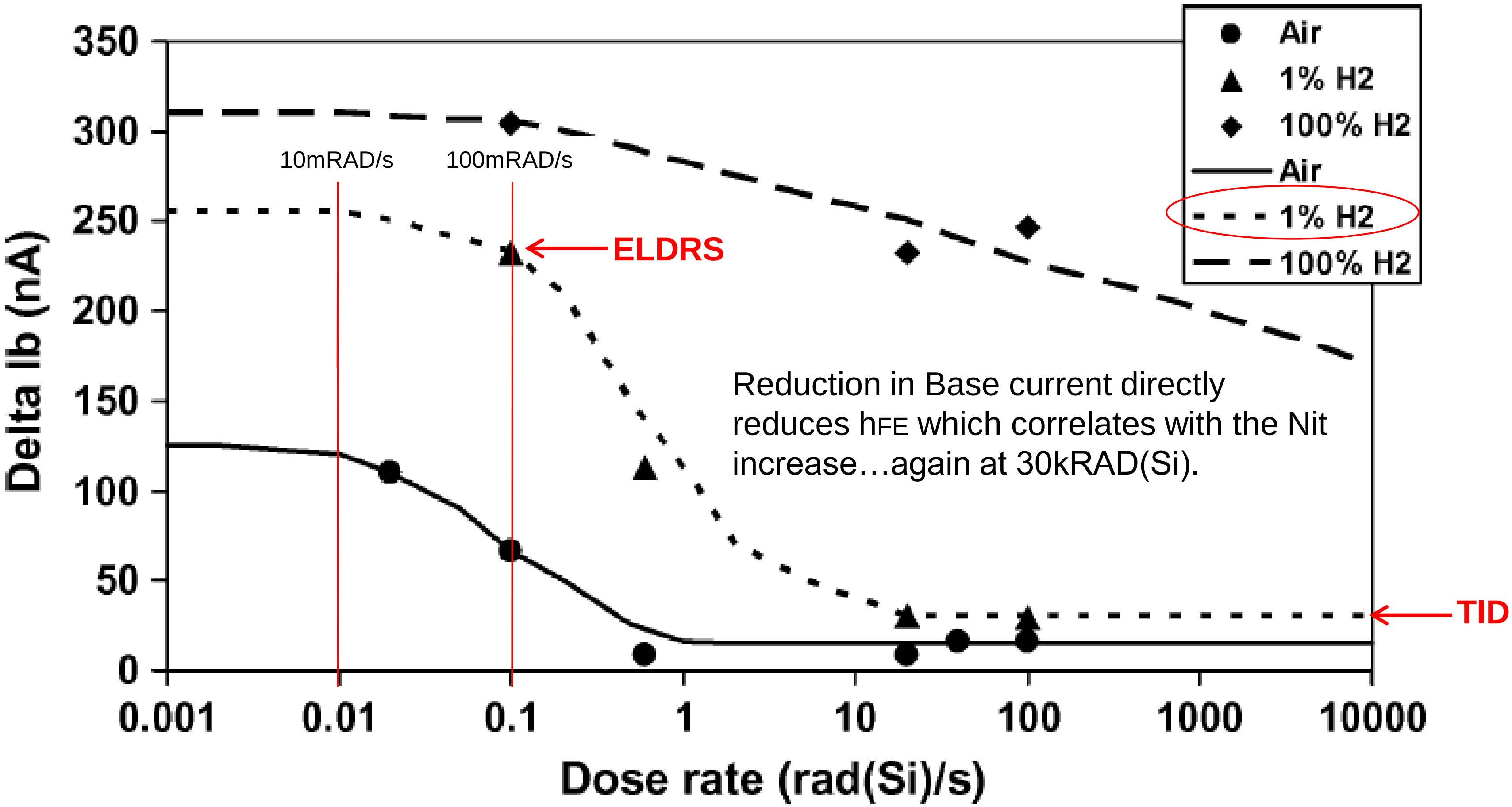
Precedent for ELDRS vs. H2 Issues

For PNP Transistors In Linear Circuits (Discrete BJT's Likely a Bit Less)

The Effects of Hydrogen on the Enhanced Low Dose Rate Sensitivity (ELDRS) of Bipolar Linear Circuits

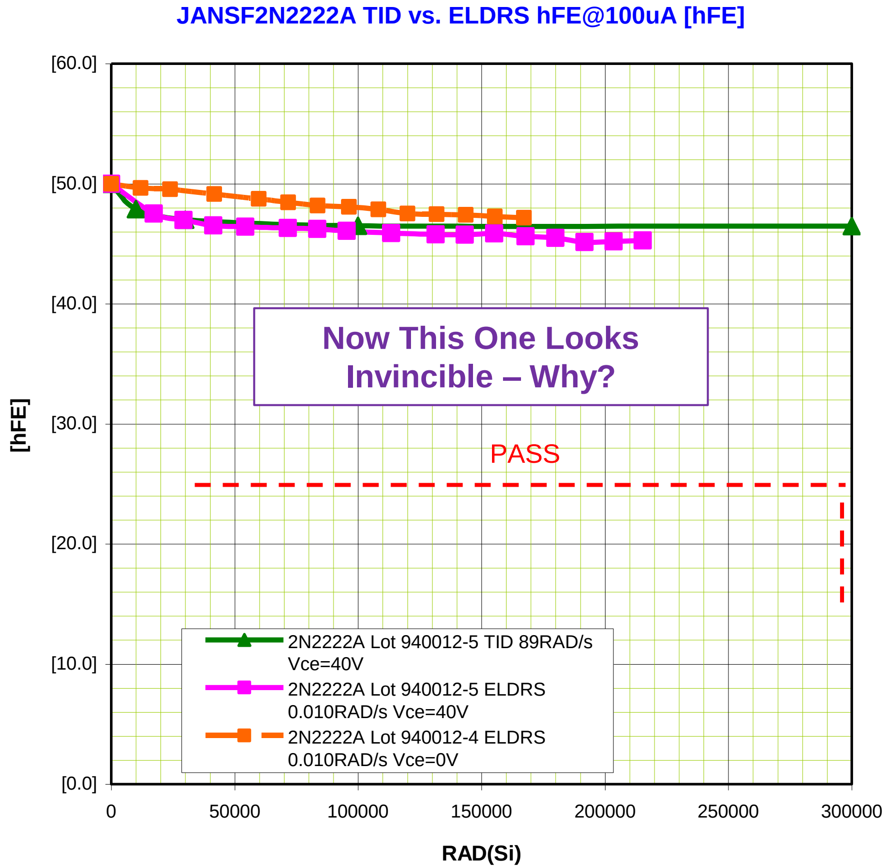
Ronald L. Pease, *Fellow, IEEE, Philippe Claude Adell, Member, IEEE, Bernard G. Rax, Member, IEEE,* Xiao Jie Chen, *Student Member, IEEE, Hugh J. Barnaby, Senior Member, IEEE,* Keith E. Holbert, *Senior Member, IEEE, and Harold P. Hjalmarson*

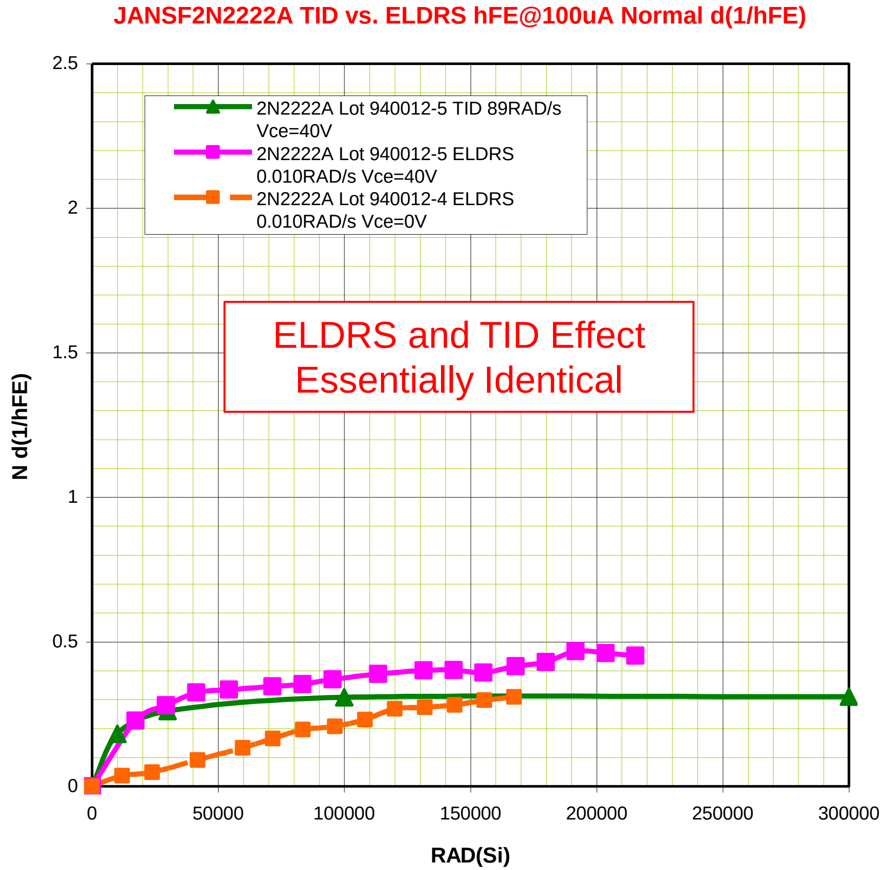


NPN Transistors TID vs. ELDRS

JANSF2N2222A TO-18 Lot 940012 W5, L2.0

NPN 50V With Added Vce=0V ELDRS Data (Not a Group D Requirement)





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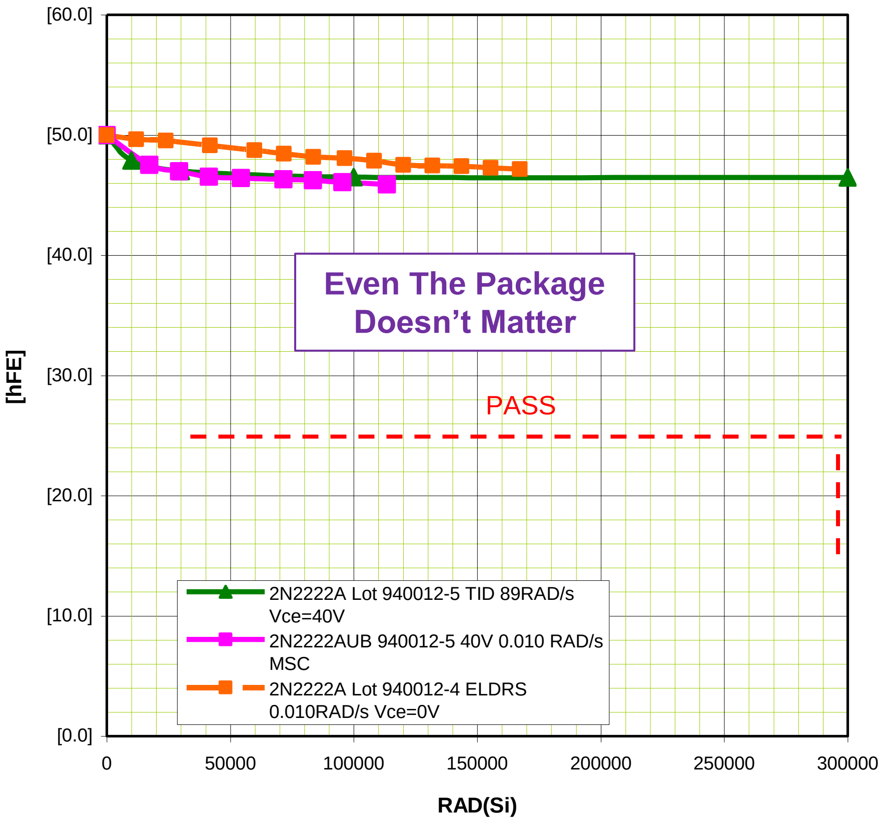
JANSF2N2222AUB Lot 940012 W5, L2.0

NPN 50V With Added Wafer 4 Vce=0V ELDRS Data (Not a Group D Requirement)

JANSF2N2222AUB TID vs. ELDRS hFE@100uA [hFE]



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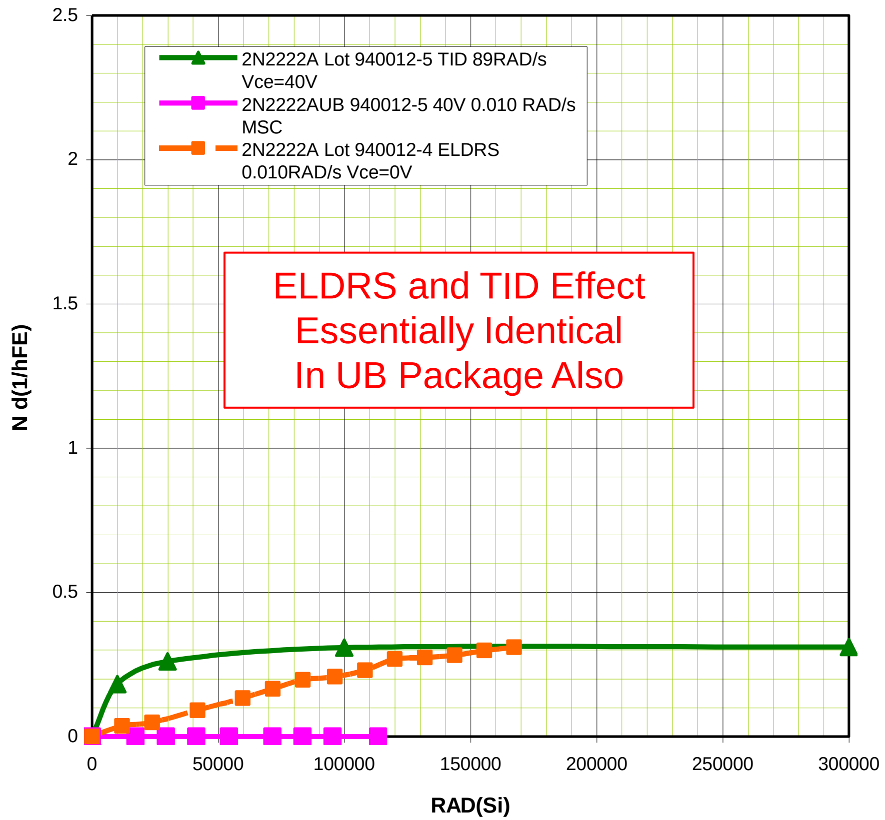
JANSF2N2222AUB TID vs. ELDRS hFE@100uA Normal d(1/hFE)



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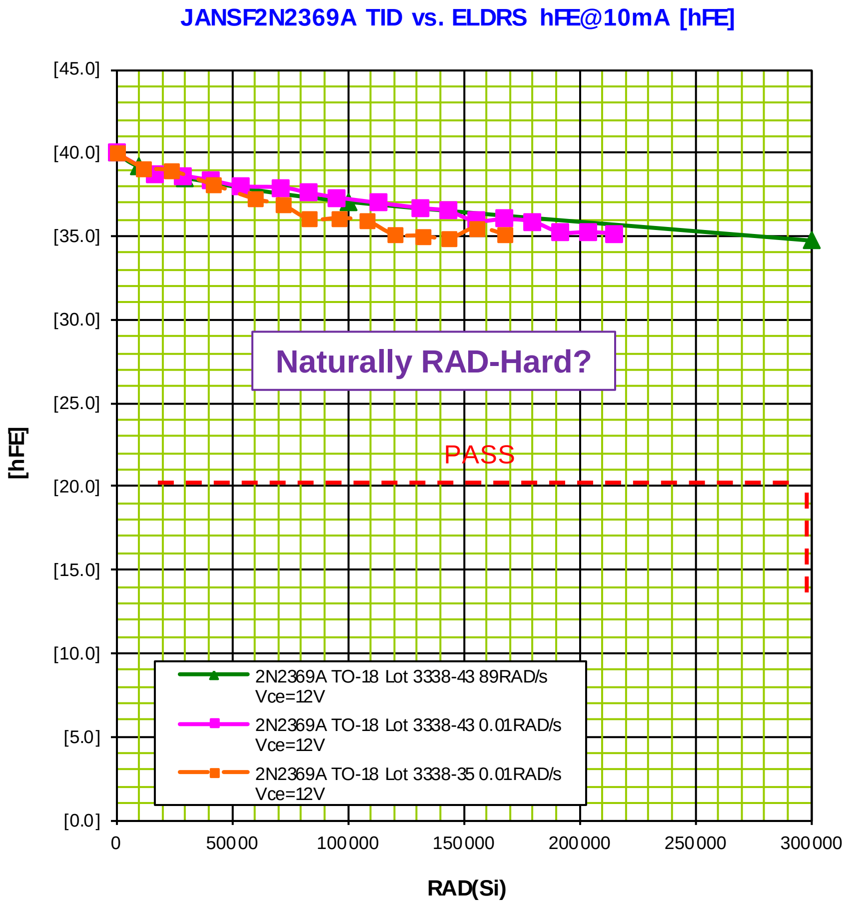
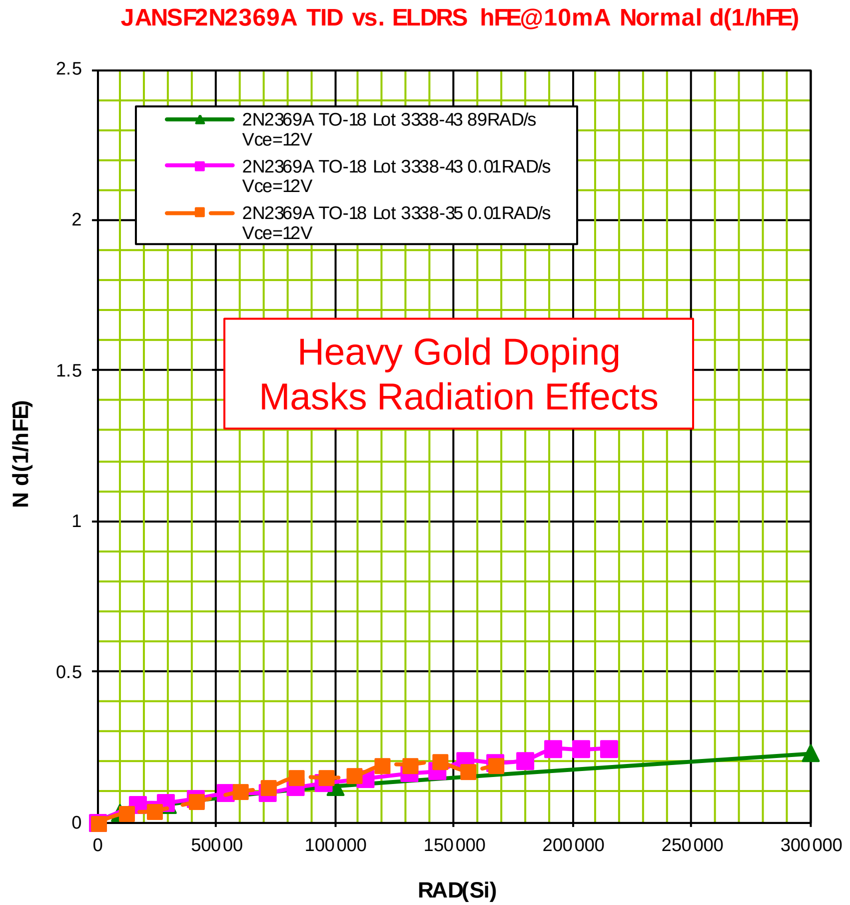
JANSF2N2369A, TO-39, Lot 3338 W43, L0.0

NPN 15V With Added Wafer 35 Vce=0V ELDRS Data (Not a Group D Requirement)





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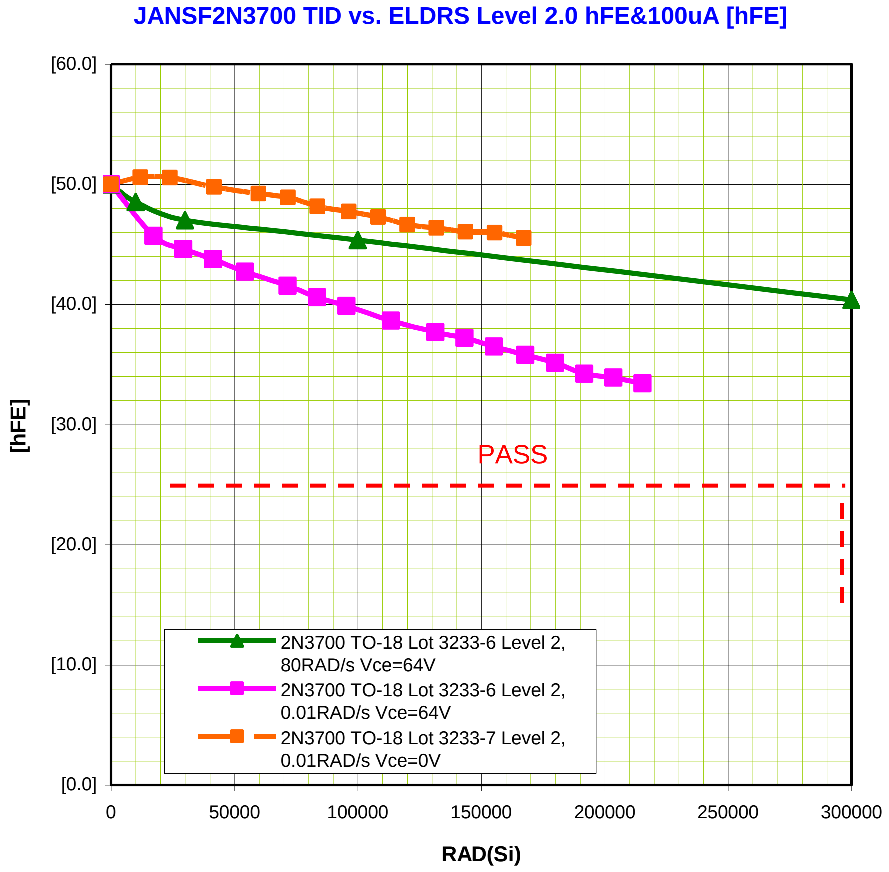
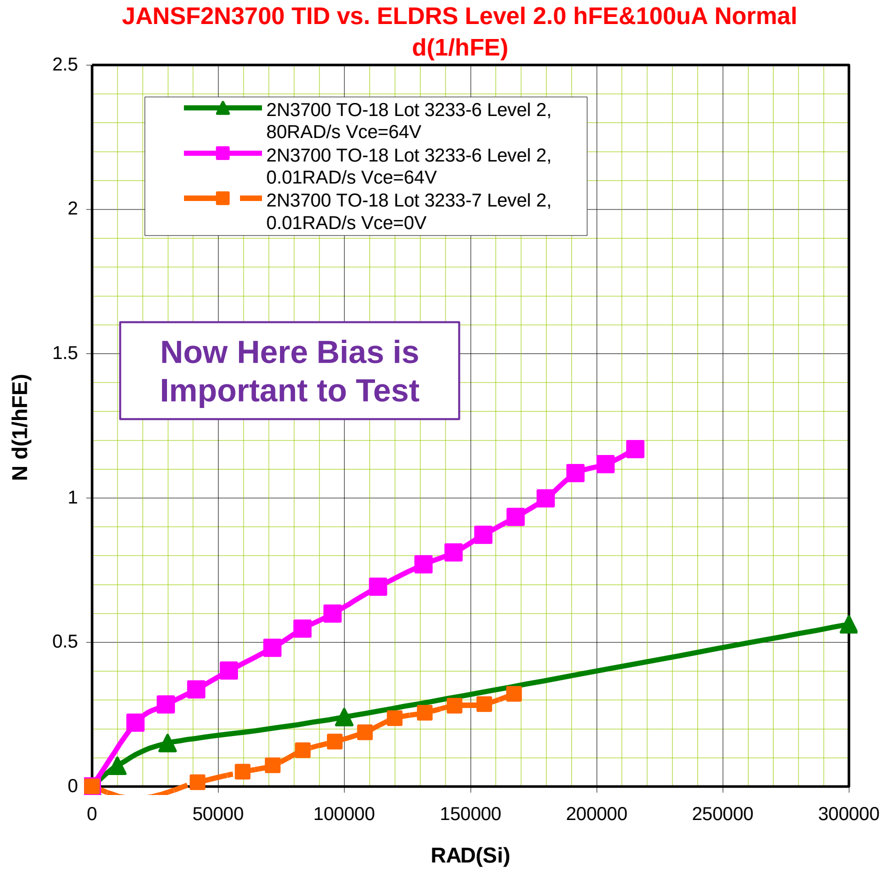
JANSF2N3700 TO-18 Lot 3233 W6, L2.0

NPN 80V With Added Wafer 7 Vce=0V ELDRS Data (Not a Group D Requirement)





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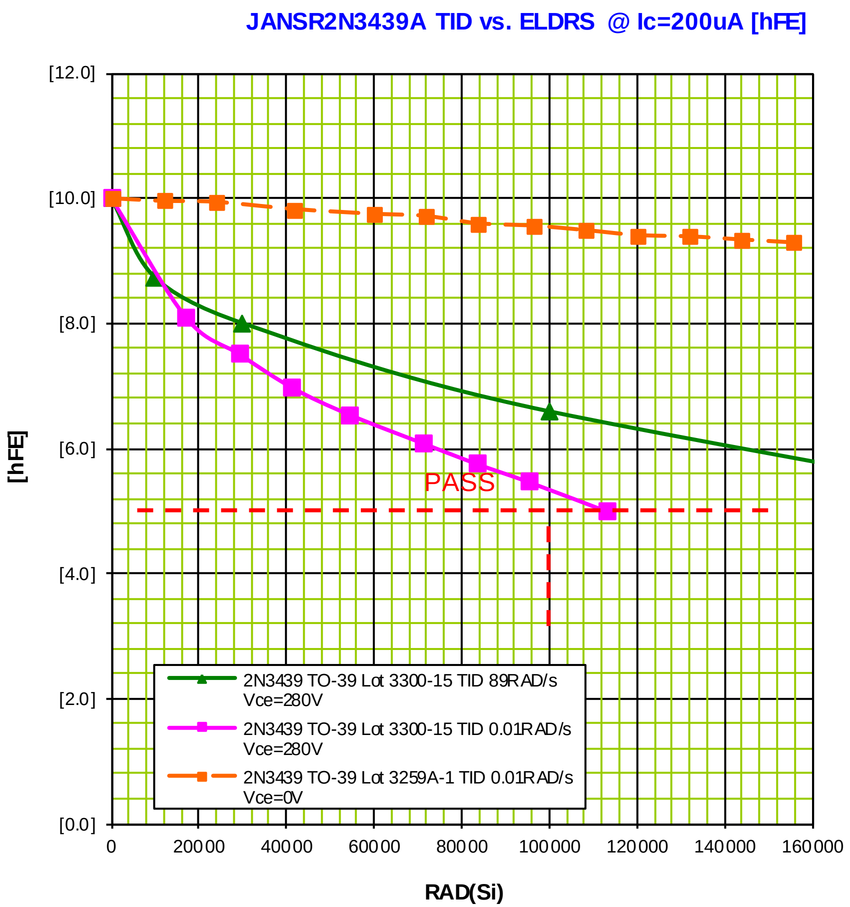
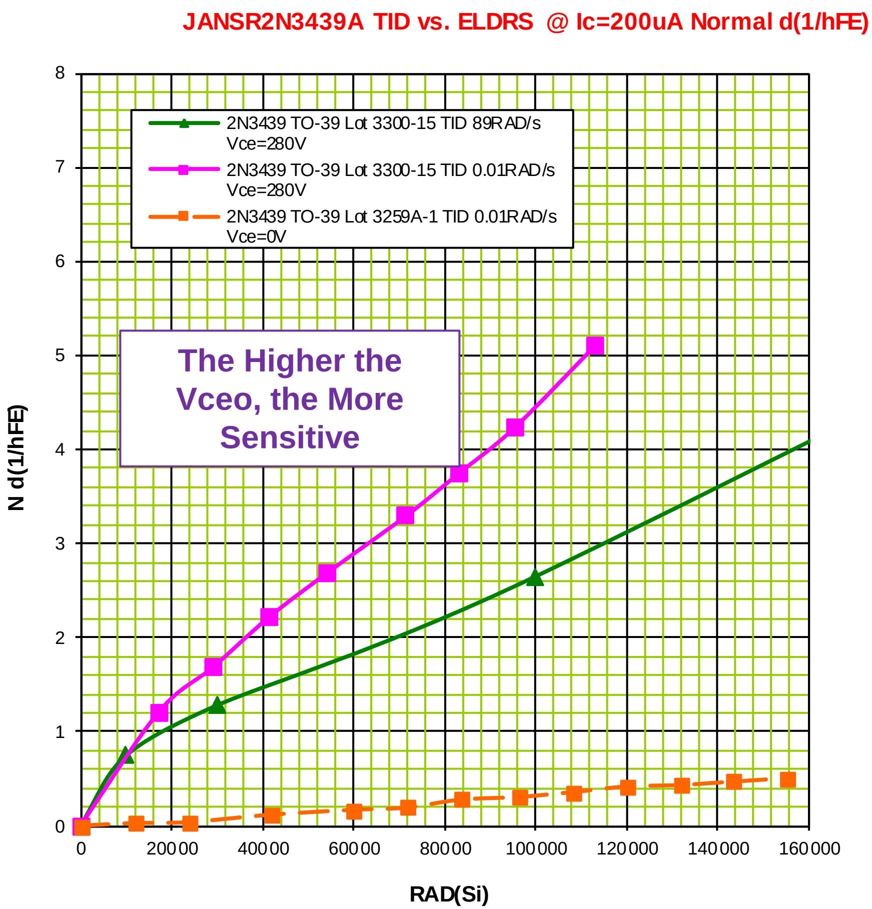
JANSR2N3439 TO-39 Lot 3300 W15, L1.5

NPN 350V With Added 3259A-1 Vce=0V ELDRS Data (Not a Group D Requirement)





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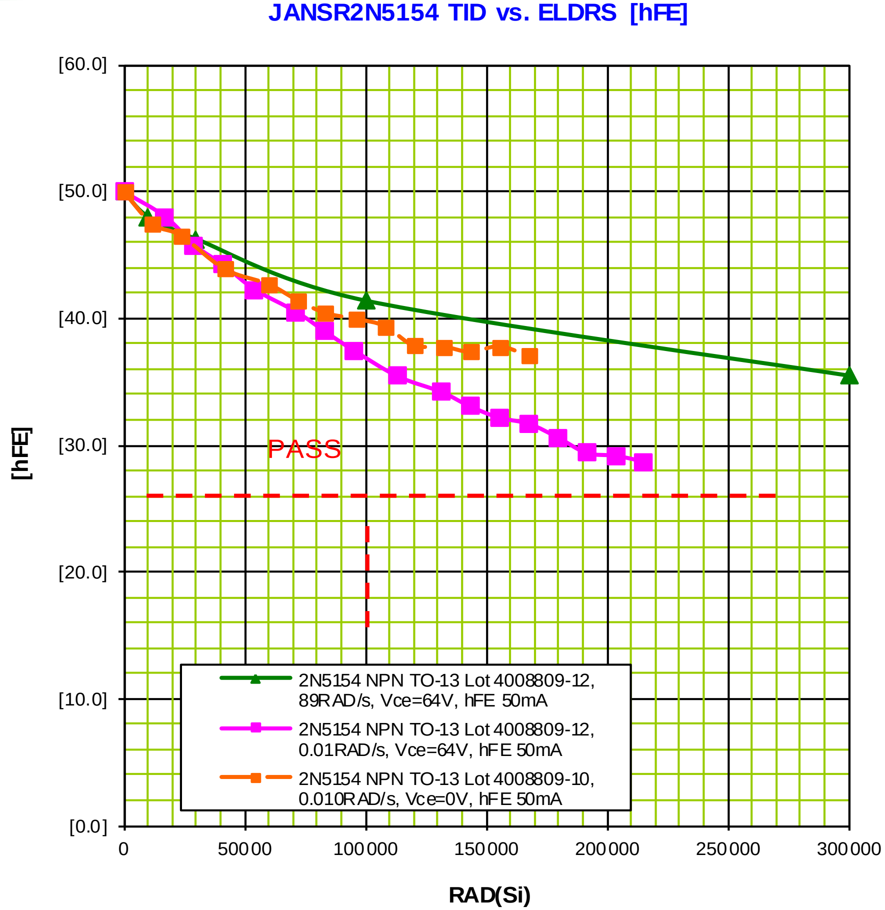
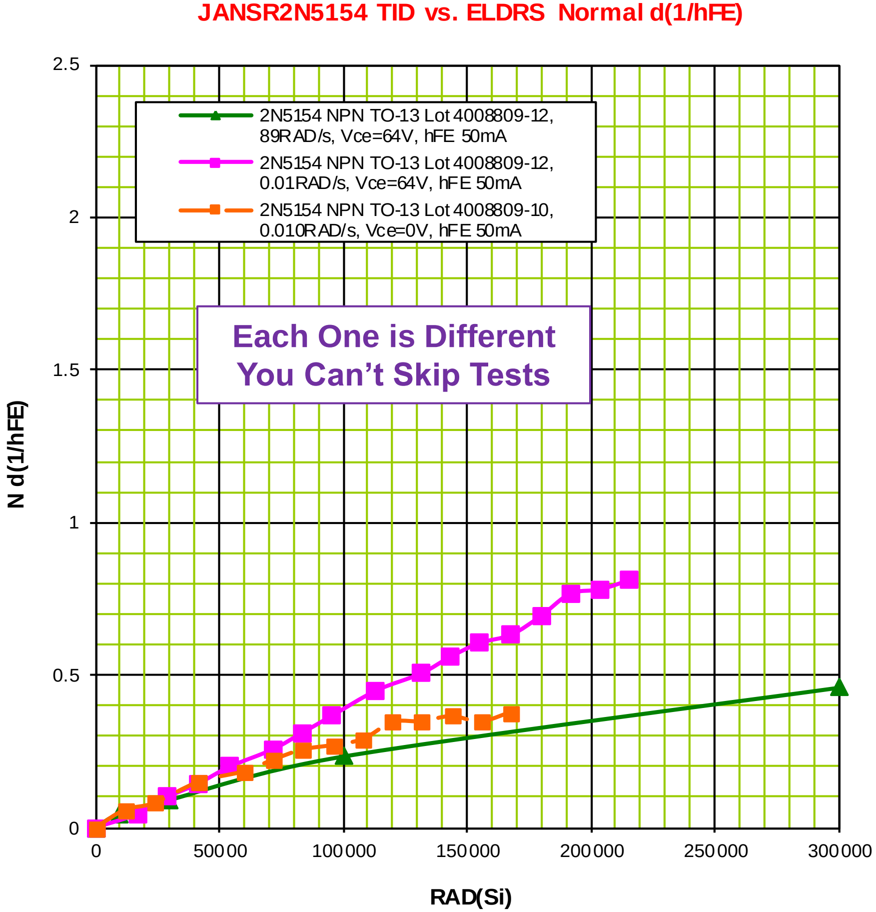
JANSR2N5154 TO-39 Lot 4008809 W12, B1.5

NPN 80V With Added Wafer 10 Vce=0V ELDRS Data (Not a Group D Requirement)





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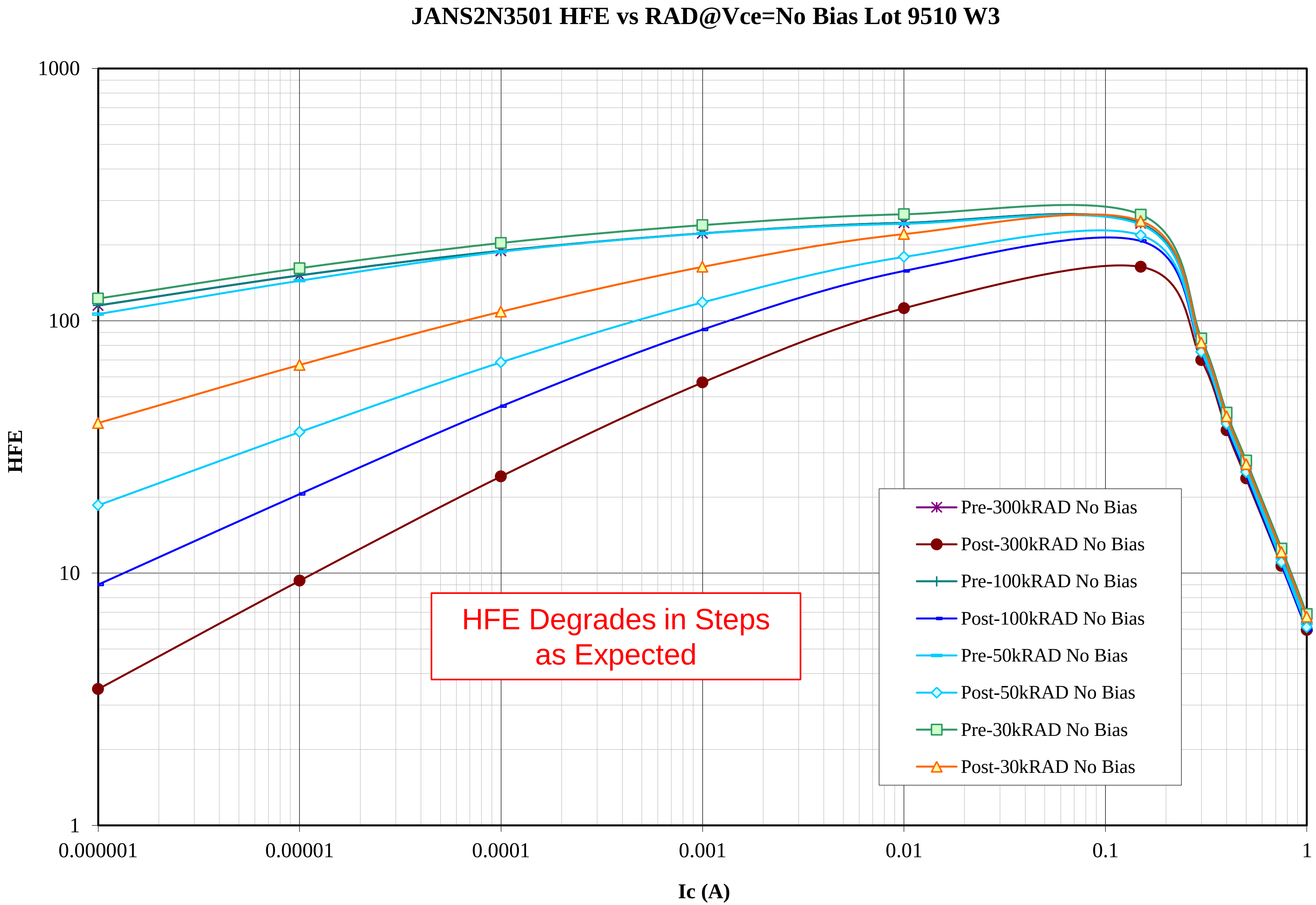
NPN Transistors - Powered

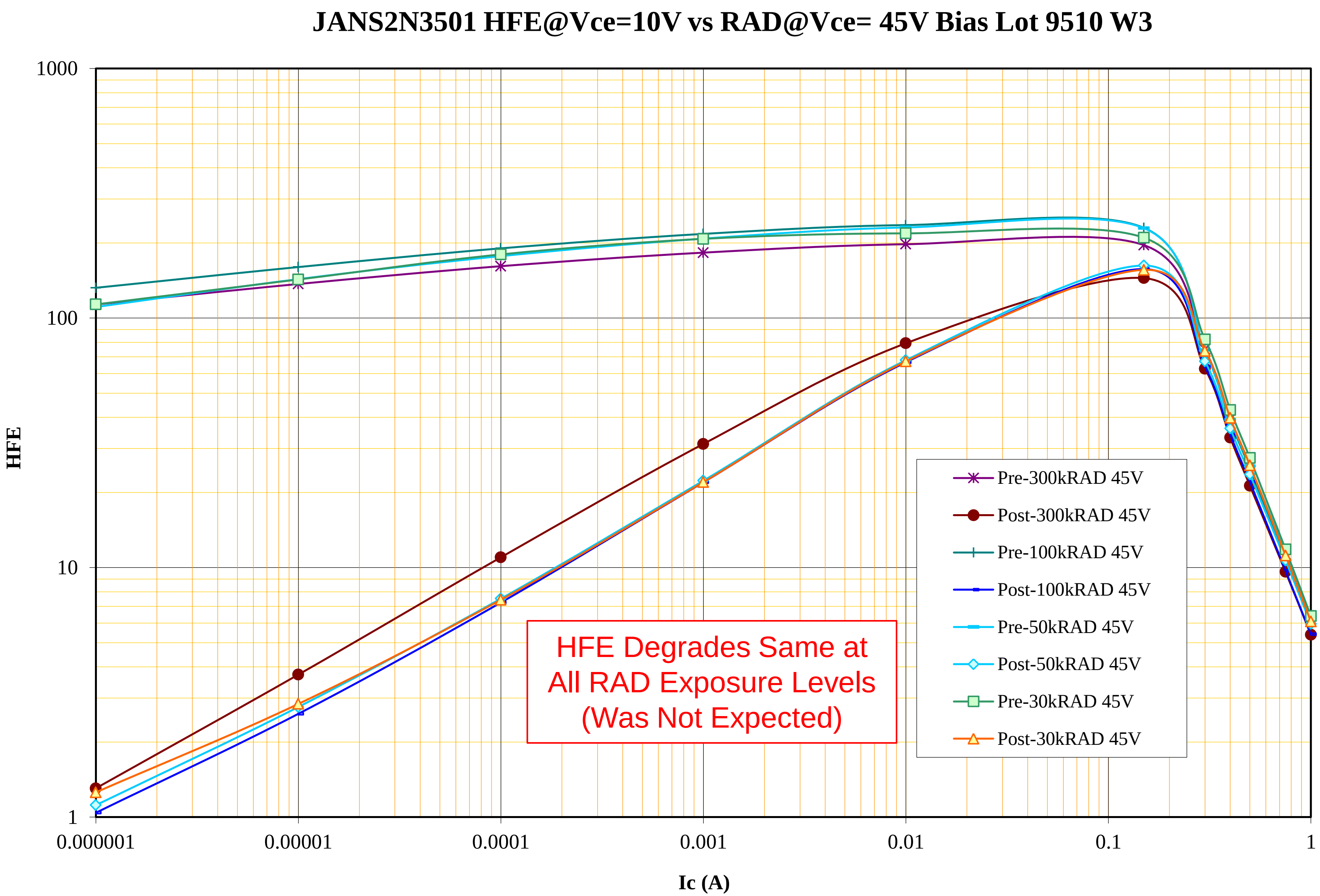
Part 1 of 4: JANS2N3501 DC0207 Not RAD Hard

NPN 80V TID Irradiated with Vce = 0V at 57RAD(Si)/s L0.0



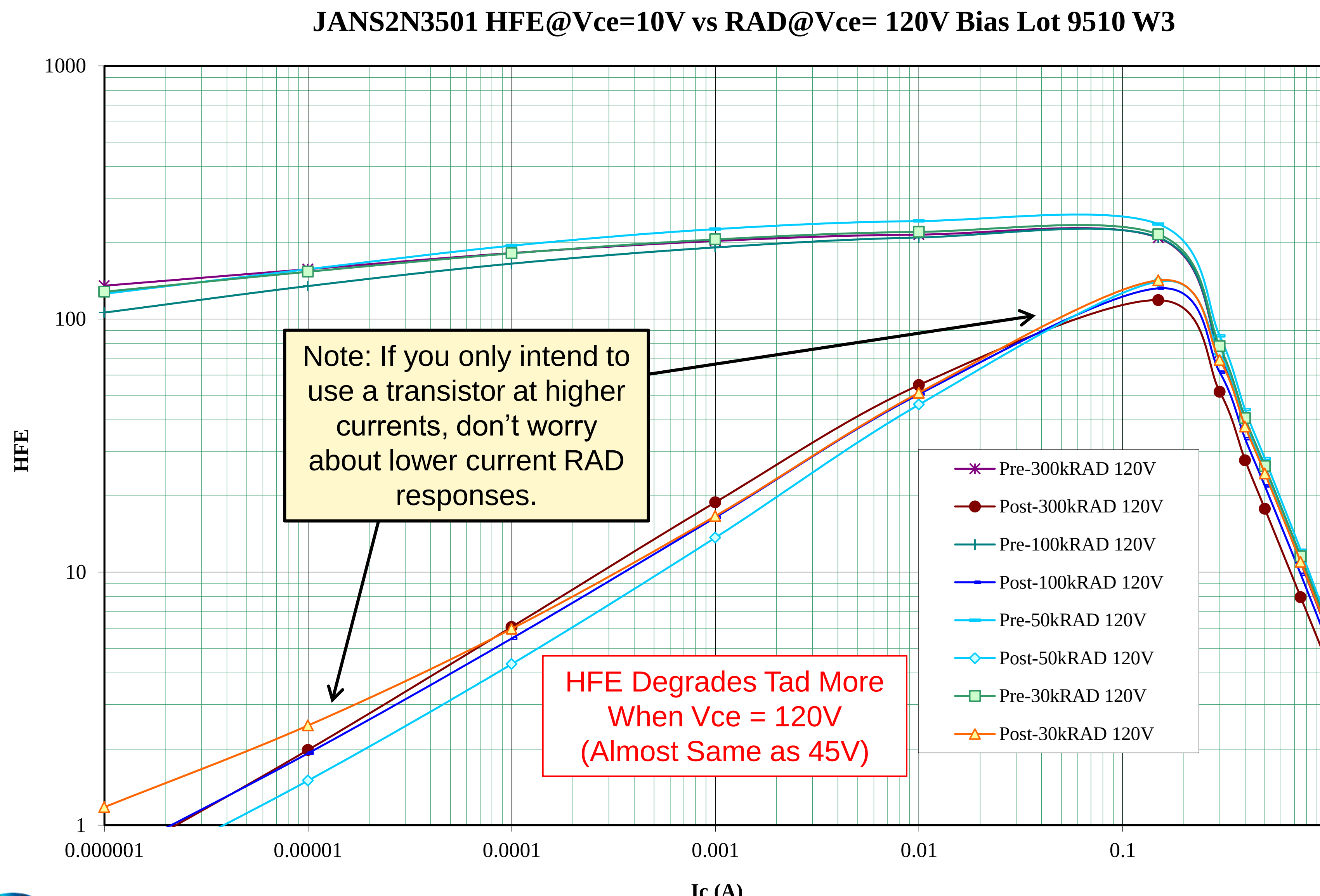
Part 2 of 4: JANS2N3501 DC0207 Not RAD Hard

NPN 80V TID Irradiated with Vce = 45V at 57RAD(Si)/s L0.0



Part 3 of 4: JANS2N3501 DC0207 Not RAD Hard

NPN 80V TID Irradiated with Vce = 120V at 57RAD(Si)/s L0.0



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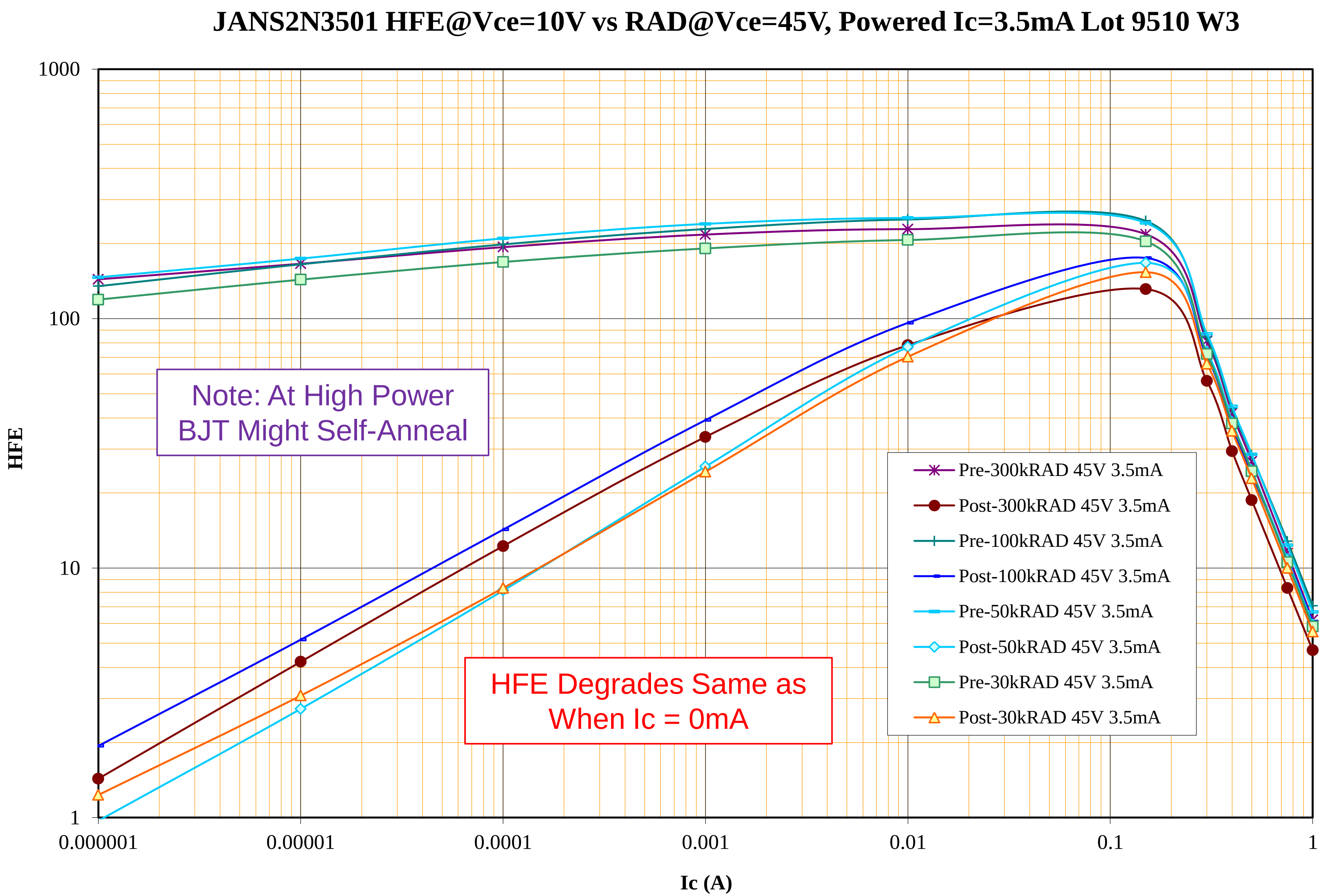
Part 4 of 4: JANS2N3501 DC0207 Not RAD Hard

NPN 80V TID Irradiated with Vce = 45V Ic=3.5mA at 57RAD(Si)/s L0.0



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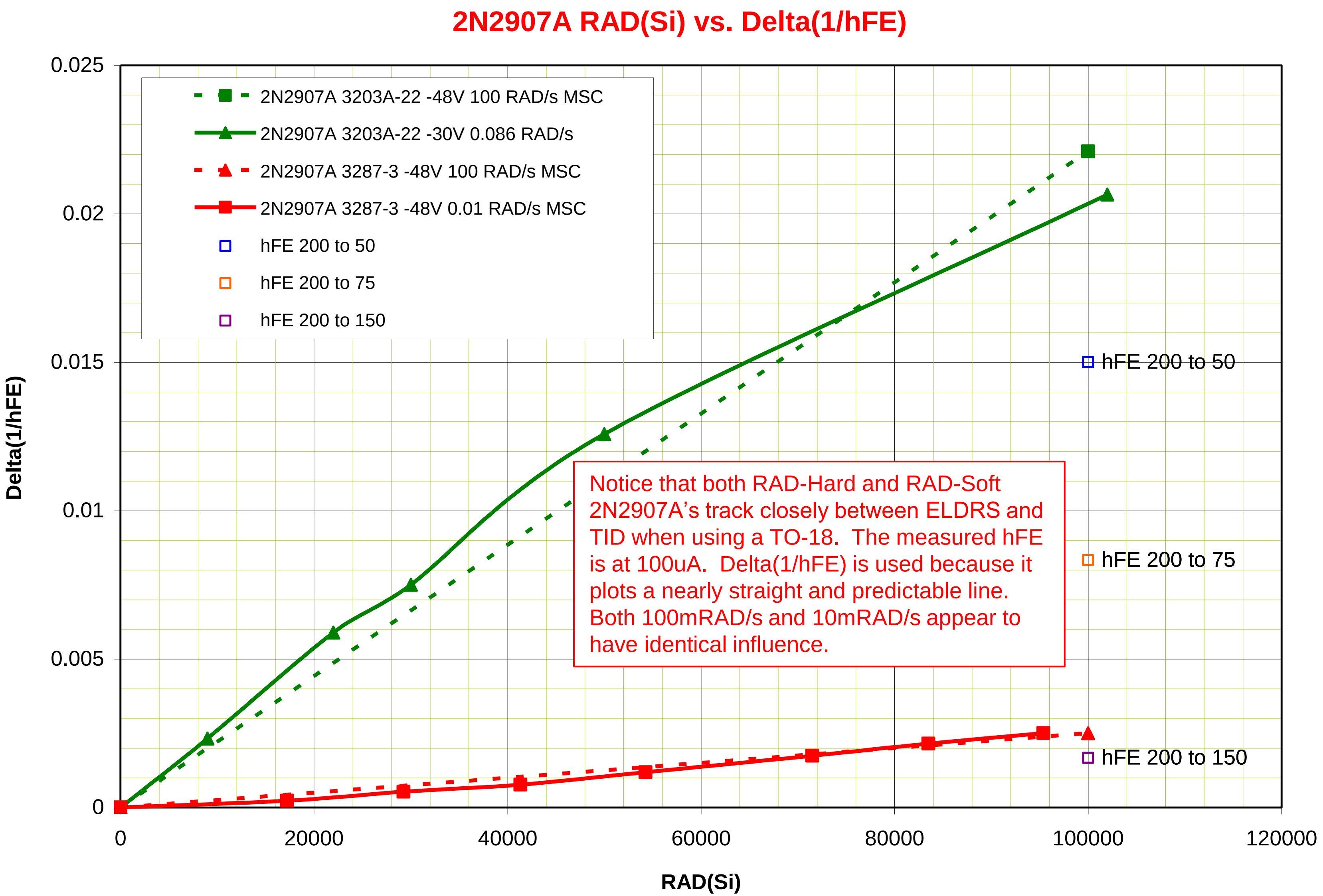
ELDRS 100mRAD/s versus 10mRAD/s

ELDRS vs. TID: JANSR2N2907A



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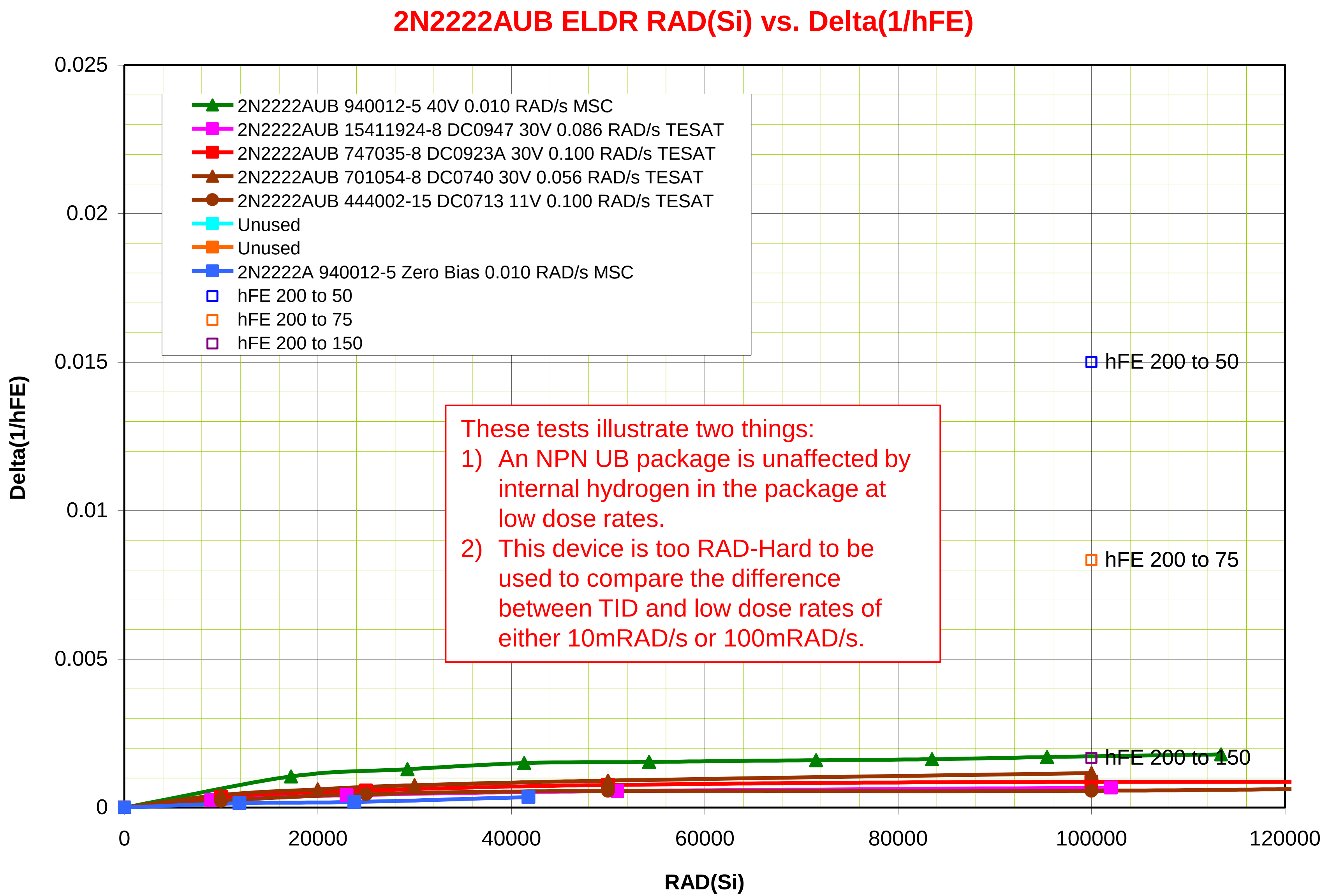
ELDRS vs. TID: JANSR2N2222AUB



These tests illustrate two things:

1) An NPN UB package is unaffected by internal hydrogen in the package at low dose rates.
2) This device is too RAD-Hard to be used to compare the difference between TID and low dose rates of either 10mRAD/s or 100mRAD/s.

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To Be Sure

Minimum RAD Requirements for Discrete

1) Do…ELDR 100mRAD/s at 80% Rated Bvceo
   Small Die Sample = 11 pieces, all ELDRS testing

2) Do…ELDR 100mRAD/s at Vce = 0V

3) Do…ELDR in Final Package (not Surrogate)

4) Do…TID at 80% Rated BVceo (Original TM1019)
   Small Die Sample = 10 pieces, all TID testing
   Required for Group D.

5) Do…TID at Vce=0V Only if Response Unknown
   Not required by Group D but better do for PNP

6) Do…Consider ELDR 100mRAD/s in Lieu of TID
   (100kRAD only takes about 2-Weeks)

Microsemi's Response to this Need

Since JAN only specifies TID, Use MSR/MVR:

1) Get…ELDR 100mRAD/s at 80% Rated BVceo
2) Get…ELDR 100mRAD/s at Vce = 0V
3) Get…ELDR in Final Package (not Surrogate)
4) Get…TID at 80% Rated BVceo (Original 1019)
5) Get…TID at Vce=0V Only if Response Unknown

Wish List

Space Community Expressed Wish List

1) Supply Third Party DPA on Received Lot

Must be independent enough to satisfy Government contract requirements. Could do DPA on entire lot as SOP but for each shipment would have to be a custom line item.

2) Opportunity for Audited Pre-Cap Visual

Logistics can be tricky. Pre-cap must be done immediately before capping.

Photographic record considered except marking and serialization always done after capping.

User resident inspector?

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Appendix – Microsemi ELDR Facility

Our ELDR System

Bias Levels = 48
Positions = 576 Total (288/Side)
Both 100mRAD/s and 10mRAD/s

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Programmable Bias Modules in Action

Bias Levels = 48
Positions = 576 Total
Both 100mRAD/s and 10mRAD/s

Each of the 48 Bias Channels has its own power source with the voltage and polarity locked in with a Program Card.

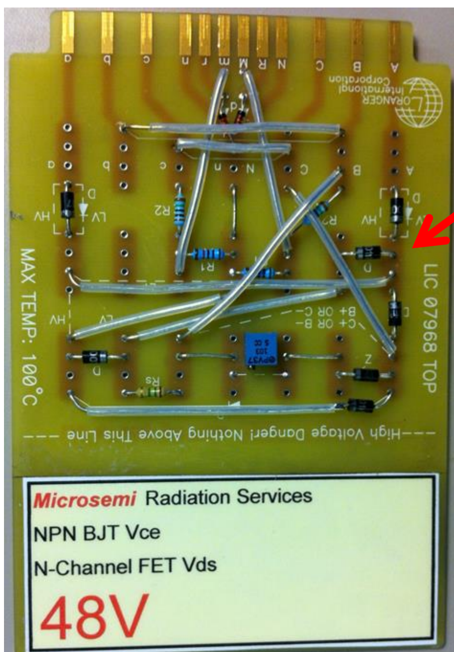
How Auto Programming Box Gets its Bias

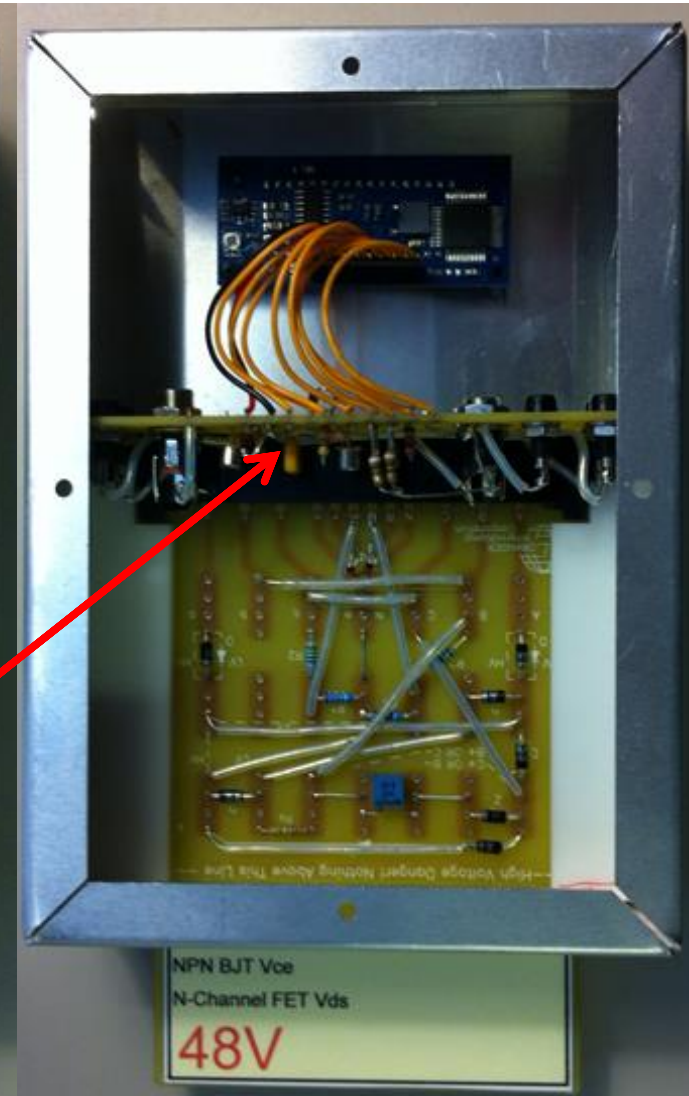
Insert and Presto!
One of 48 Channels Receives a Unique Bias Voltage (0-1000V) but up to 1200V if Needed.

Flip the Card and the Polarity is Reversed.

Card Can be Trimmed for Spot-On Voltage Settings if desired.

Meter Readout is 1% and Continuous as to What bias the Parts are actually Receiving.





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View From the 10mRAD Side

Bias Levels = 48
Positions = 576 Total
Both 100mRAD/s and 10mRAD/s

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100mRAD/s Report on One Run

Status of This Information in Main Table (1=Active, 0=Inactive)	=	1
Package Number or Description	=	11
Part Number	=	JANSR2N2907AUB
Date Code	=	1243
Wafer Lot Number	=	F2080-2
Assembly Lot Number or Work Order Number	=	WO#45635
SampleSize	=	5
Record Run Number	=	100038
Board Number (1 to 6)	=	2
Channel BJT A,B,C or D or FET A or B and AG or BG	=	A
Board Socket Numbers Example: 1 to 10 6 to 10 (0 = n/a)	=	1 to 5
Required Bias Voltage (+/- V)	=	-48
FET Gate Bias Voltage (+/- V)	=	
Note, Comment or Request	=	7.1kRAD (21.3kRAD Total) JMM
Desired Gamma Target Dosage For This Run (RAD)	=	7,100
Run is On? (1=Yes, 0=Closed, Blank=Not Started	=	0
Start Date (Blank = Not Yet) Date and Time (m/d/yy h:mm AM)	=	Wed 10/23/13 11:41 AM
Projected Finish Date (Blank = Not Yet) Date and Time (Day, m/d/yy h:mm AM)	=	RAD Run Ended
Actual Finish Date (Blank = Not Yet) Date and Time (m/d/yy h:mm AM)	=	Thu 10/24/13 7:52 AM
Total Drop Out Interrupt Time if Any (0=None) in Hours	=	0
Actual Received Gamma Dosage (RAD)	=	7,103
Average Dose Rate Today at Selected Part and Board (mRAD/s)	=	97.8
Test Board Number	=	LIC 07963
Package Type	=	UB (LCC3)
Device Type	=	BJT
Number of Biases Required (1=BJT, Diode and 2=FET)	=	1
Maximum Positions per Channel	=	12
Socket Mounting Plane Height (in)	=	0.245
Chip Height Above Socket (in)	=	-0.04

Portion of the automatically generated irradiator report.

Start times and stop times automatically track the age of the source plus the height of the package and socket plus bias conditions.

A copy of the report is recorded electronically plus another copy is printed out to be attached to te traveler.

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Summary

- Slash Sheets only require TID at Vce=80% BVceo
- Mil-Std-750 Test Method 1019 allows ELDRS as substitute for TID if customer agrees. DLA says if customer agrees, it's OK with them.
- But how do you get a Part Number that Guarantees all this?
  Answer: A Parallel Universe of Part Numbers
    JANSR2Nxxxx becomes **MSR**2Nxxxx
    JANTXV2Nxxxx becomes **MVR**2Nxxxx

  BJT ELDRS 100mRAD/s at 80%Bvceo Bias, 11 Samples
  BJT ELDRS 100mRAD/s at Zero Bias , 11 Samples
  Taken from the actual JANS and JANTXV Line.

  Since 100mRAD/s and 10mRAD/s Shown as Equivalent,
  Results in a few weeks at a Fraction of the Cost.

Thank You

Microsemi Corporation (MSCC) offers a comprehensive portfolio of semiconductor and system solutions for communications, defense & security, aerospace and industrial markets. Products include high-performance and radiation-hardened analog mixed-signal integrated circuits, FPGAs, SoCs and ASICs; power management products; timing and synchronization devices and precise time solutions, setting the world's standard for time; voice processing devices; RF solutions; discrete components; security technologies and scalable anti-tamper products; Ethernet solutions; Power-over-Ethernet ICs and midspans; as well as custom design capabilities and services. Microsemi is headquartered in Aliso Viejo, Calif., and has approximately 3,600 employees globally. Learn more at www.microsemi.com.

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Microsemi Corporate Headquarters
One Enterprise, Aliso Viejo, CA 92656 USA
Within the USA: +1 (800) 713-4113
Outside the USA: +1 (949) 380-6100
Sales: +1 (949) 380-6136
Fax: +1 (949) 215-4996
email: sales.support@microsemi.com