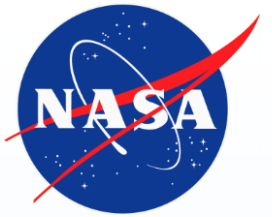

Silicon Schottky Diode Safe Operating Area

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Outline

- Background
- Results to Date
- Case Study: Testing for a Flight Project
- Schottky Diode Derating Guideline
- Conclusions

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Introduction

- In 2011/2012, GSFC observed failures in the output Schottky diodes of DC/DC converters
  - Independent testing of the diodes was undertaken to determine their vulnerability to heavy ions
- Until this point, diodes generally were not considered to be susceptible to SEEs
- Power MOSFETs are derated, not only for electrical performance, but also for SEEs, when operating in a radiation environment

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Derating Requirements for Diodes

- Currently, only NASA GSFC Standard EEE-INST-002 Instructions for EEE Parts Selection, Screening, Qualification, and Derating

Table 4 DIODE DERATING REQUIREMENTS

Diode Type	Stress Parameter	Derating Factor
General Purpose, Rectifier, Switching, Pin/Schottky, and Thyristors	PIV	0.70
	Surge Current	0.50
	Forward Current	0.50
	Maximum Junction Temperature 1/	0.80

* PIV – Peak Inverse Voltage, also known as reverse voltage

- This standard requires the reverse voltage to be derated to 70% of the datasheet's maximum specified value

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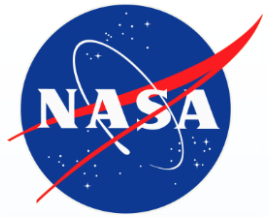

Results to Date

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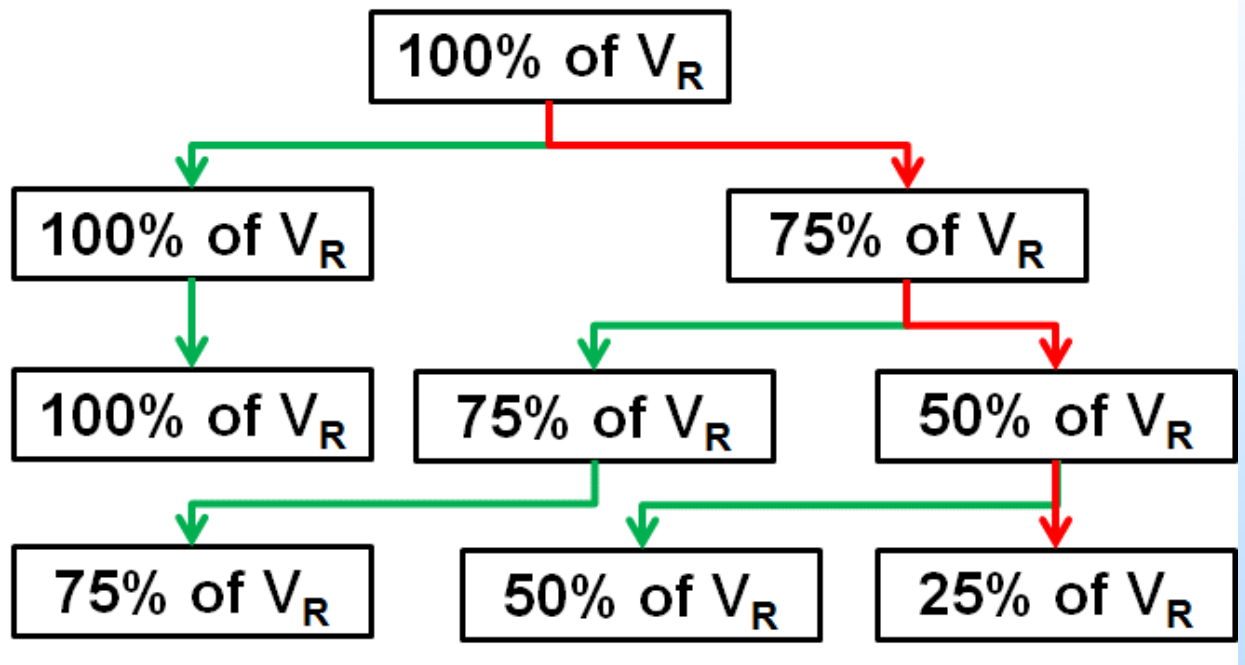
Test Facilities and Technique

- All parts were tested at LBNL's 88" cyclotron with 1233 MeV Xe (LET = 58.8 MeV-cm^2/mg)
- All diodes were irradiated under reverse bias and at room temperature
- After each beam run, V_F, V_R, I_F and I_R were measured



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Parts Tested

- 53 Schottky diodes from 11 manufacturers
- Reverse voltages range from 40 V to 600 V
- Forward currents (per diode) from 5 A to 40 A
- Within the manufacturers, high temperature, high forward voltage lines are compared to low temperature, low forward voltage and low barrier height lines

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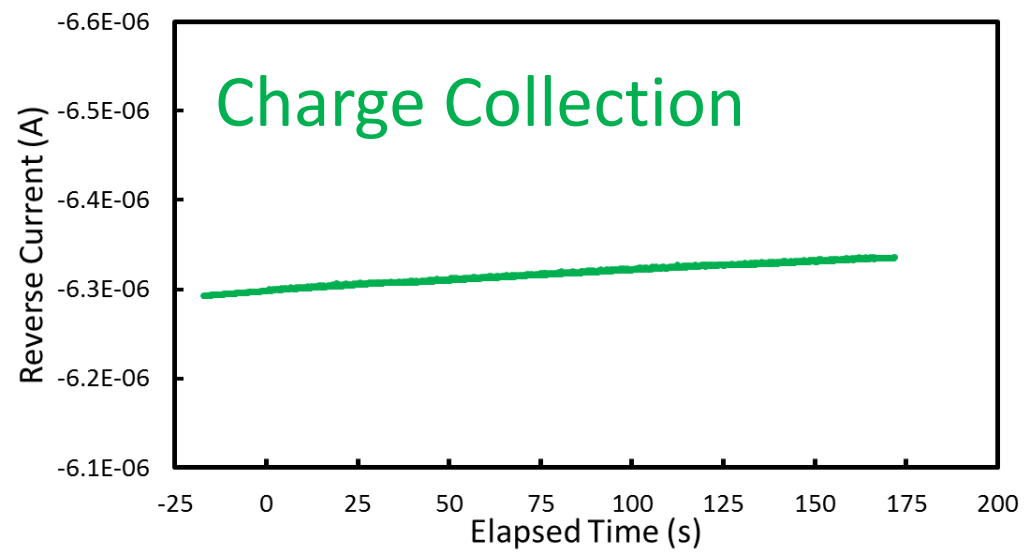
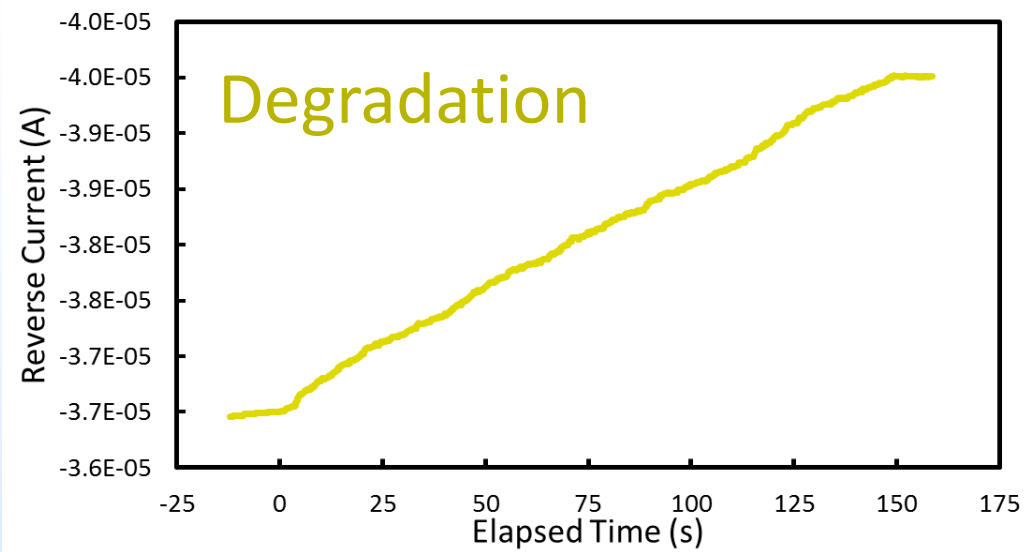
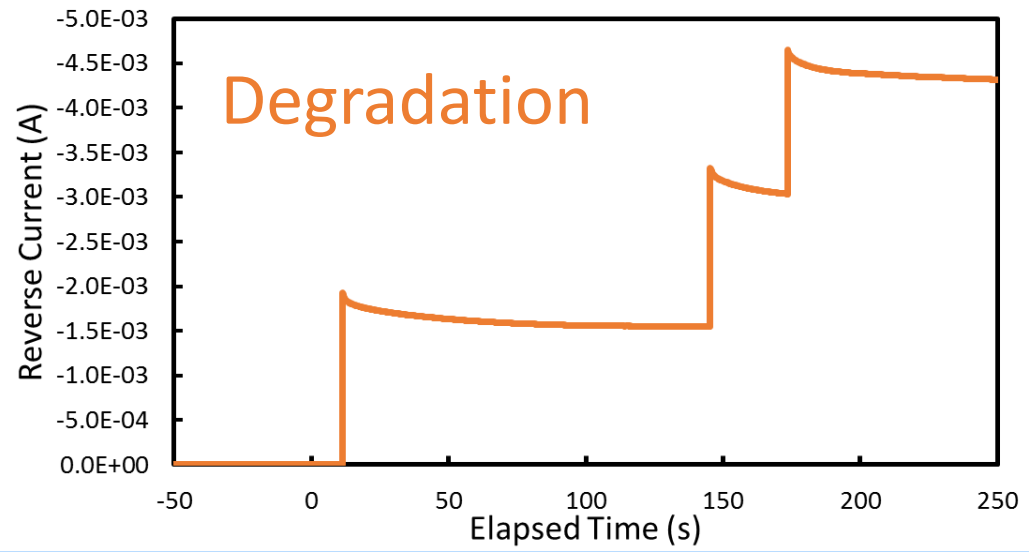
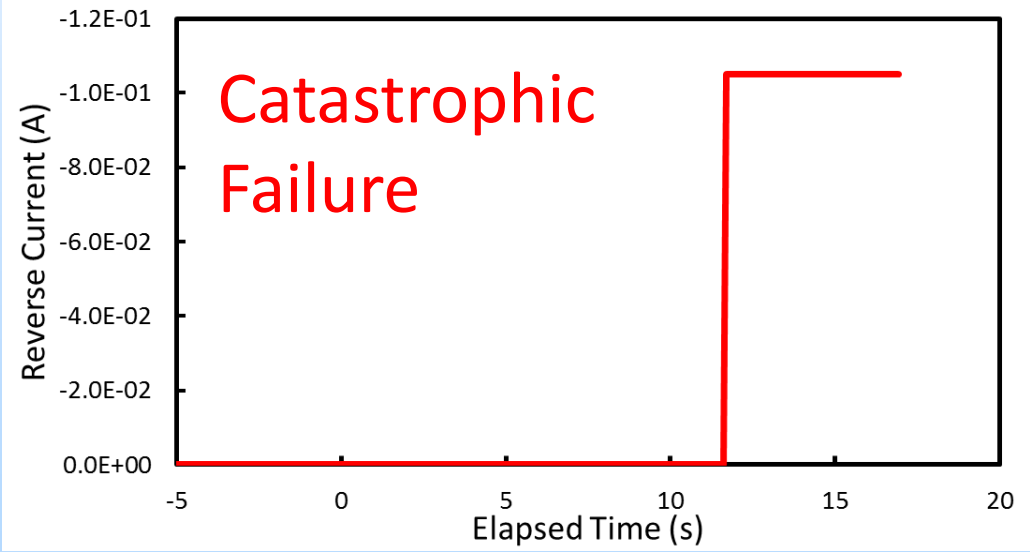
Observed Radiation Responses









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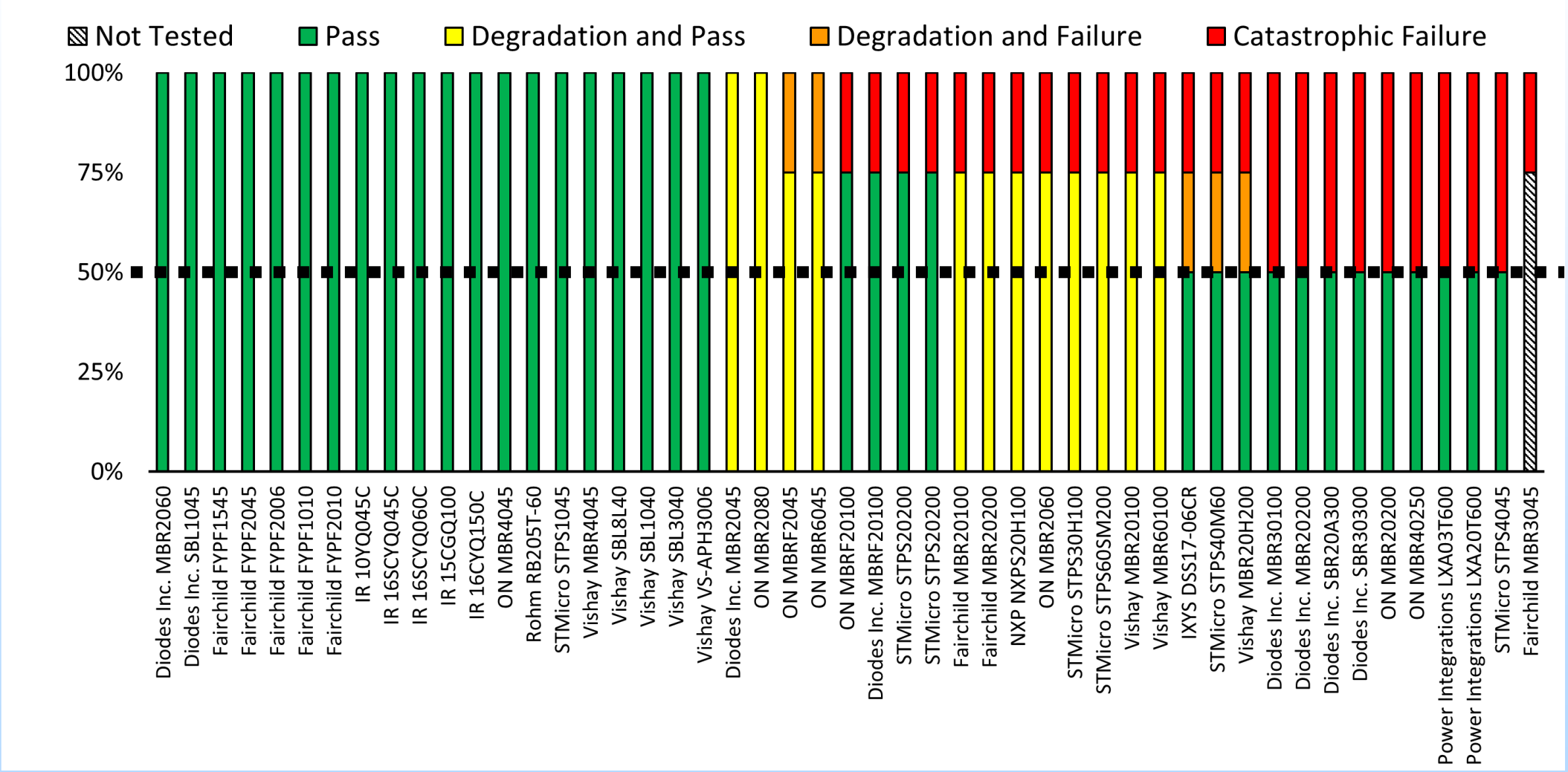
Results



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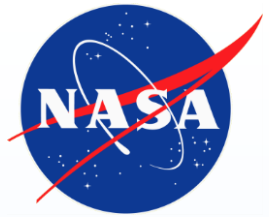

Case Study: Testing Schottky Diodes for a Flight Project

Deliverable to NASA Electronic Parts and Packaging (NEPP) Program to be published on nepp.nasa.gov originally presented at the 2016 NEPP Electronics Technology Workshop (ETW), Goddard Space Flight Center, Greenbelt, Maryland, June 13–16, 2016.

Background

- The 1N6843 was being used on the same board for two missions
  - The reverse voltage of these parts are 100 V
  - Parts were procured from two separate manufacturers, Vendor A (JANS) and Vendor B (JANTXV)
  - Normal application reverse voltage is ~60 V and worst case application reverse voltage is ~82 V
- There are currently no mission **radiation** requirements for diodes; so destructive SEEs requirements were used for this testing
- Unlike the previous work, these parts were tested at TAMU's Cyclotron Institute and finer step sizes were taken

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Mission Single-Event Requirements

- Destructive Events – Single-Event Latchup
  - All EEE parts shall be immune to destructive SELs up to an LET threshold for SEL of 37 MeV-cm^2/mg.
  - For devices with SEL thresholds between 37 MeV-cm^2/mg and 75 MeV-cm^2/mg, an evaluation of the probability and impact of destructive events shall be conducted

- Destructive Events – Single Event Burnout and Single Event Gate Rupture
  - All power transistors shall have a SEGR and SEB LET threshold of greater than 37 MeV-cm^2/mg when biased at 133% of the application peak V_{DS} or V_{CE}.
  - MOSFET and BJT devices shall be derated to 75% of the highest-passing V_{DS} or V_{CE} respectively as determined by worst-case accelerated ground test data at an LET of greater than 37 MeV-cm^2/mg.

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Test Results

Ion Species	LET (MeV-cm²/mg)	Vendor A	Vendor B
Cu	20.3	Pass	Pass
Ag	43.6	Pass	Degradation and Pass (85 V)
Pr	60	Pass	Degradation and Pass (70 V) Catastrophic Failure (95 V)
Ta	79	Degradation and Pass (90 V) Catastrophic Failure (95 V)	Degradation and Pass (55 V) Degradation and Failure (65 V)

- Using 70% electrical derating, the parts from Vendor B could potentially experience degradation and catastrophic failure
  - Should be derated to 60 V based on SEB/SEGR requirements
- Vendor A would not be approved based on the SEB/SEGR requirements or the electrical requirements
  - Worst case reverse voltage should be 70 V
- Failure analysis is being conducted to determine any latent damage in the parts that experienced degradation

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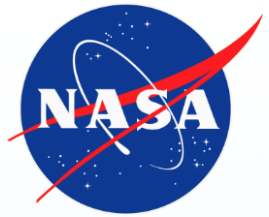

Schottky Diode Derating Guideline

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NASA Electronic Parts and Packaging Guideline

- Guideline will require a 50% derating from the datasheet's maximum reverse voltage
  - This strongly suggests that parts, when operating in a heavy-ion environment, will not experience a catastrophic failure or degradation

- Also included in the document will be a discussion on the failure mechanism
  - This will include the failure analysis from the parts in the case study
  - Degradation may be similar to "non-destructive" SEL where the effect of latent damage is unknown on long-term performance

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Conclusions

- Schottky diodes are susceptible to destructive SEEs
- No failures observed at 50% (or below) of rated reverse voltage
- NEPP guideline is being written to require Schottky diode reverse voltages to be derated to 50% of the maximum specified in the datasheet
- Using this derating, parts discussed in this case study would not experience degradation or catastrophic failure on orbit

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