Application Note

GaN FETs

GaN FET Current Increase Due to Heavy Ion Testing

Abstract

Heavy ion single event testing of the Renesas 40V, 100V, and 200V GaN FETs showed that all three of the device types experienced an increase in I_{DSS} current under certain conditions of V_{DSS} and LET. Using the results of this testing and the appropriate parameters for a geosynchronous orbit in the single event simulation program CREME96, it was possible to show that the increase in current in a typical geosynchronous orbit would be inconsequential.

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Related Literature

For a full list of related documents, visit our website:

- ISL70020SEH, ISL70023SEH, ISL70024SEH device pages

1. Analysis

Table 1 is a summary of the worst case I_{DSS} current increase of the four samples that were tested at the Texas A&M University (TAMU) Radiation Effects Facility of the Cyclotron Institute. Before and after each irradiation the I_{DSS} current (two terminal blocking current) was logged with the part in the blocking mode. The I_{DSS} current was also measured for the absolute maximum V_{DSS} voltage ratings before and after each irradiation. The measurements and irradiations were carried out at ambient temperature (~25°C) to a fluence of $2.5x10^6$ions/cm^2 at a flux of approximately $1x10^4$ions/(cm^2-s). This brought the total fluence for each device type at each species and V_{DSS} combination to $1x10^7$ion/cm^2. Each combination of ion species (4) and V_{DSS} (3) was tested on four fresh DUTs. Additional details on this testing can be found in the relevant test reports on the ISL70020SEH, ISL70023SEH, ISL70024SEH device pages.

Table 1. Worst Case Current Increase of GaN FETs During Exposure to Heavy Ions at a Fluence of $1x10^6$ions/cm^2

Part Type	V_{DSS} (V)	Current Increase at LET		
		43Mev•cm^2/mg	60Mev•cm^2/mg	86Mev•cm^2/mg
ISL70020SEH (40V)	32	-	-	Up to 5.4µA
	40	-	-	Up to 9.0µA
ISL70023SEH (100V)	60	-	Up to 1.3µA	Up to 3.1µA
	80	-	Up to 0.5µA	Up to 4.6µA
	100	-	Up to 1.9µA	Up to 5.9µA
ISL70024SEH (200V)	120	Up to 2.0µA	Up to 7.4µA	Up to 8.9µA
	160	Up to 0.9µA	Up to 3.1µA	Up to 32.4µA
	200	Up to 6.7µA	Up to 15.3µA	SEB

As shown in Figure 1 on page 3, a CREME96 LET spectrum file was generated for a satellite in a geosynchronous orbit using all species of heavy ion particles (atomic numbers 2 – 92) with a minimum energy value of 0.1MeV/nuc. Assumptions included solar minimum conditions for worst case cosmic flux transported through 100 mils of aluminum shielding.

The integral flux in Figure 1 is expressed in terms of the number of particles incident in a solid angle about a line normal to a small area on the surface of a sphere (note that the vertical axis is in particles per meter squared per steradian second). The LET shown on the x-axis is measured in Mev•cm^2/gm. The colored lines on the plot represent the flux of particles of a given LET. For example, the green lines on the plot show the flux of particles with an LET of 43Mev•cm^2/mg (note - gram to milligram conversion required), which is the lowest measured energy that resulted in a current increase. The associated flux for particles of that energy is approximately $3.04x10^{-7}$ particles/m^2-s-sr or $3.04x10^{-11}$ particles/cm^2-s-sr.

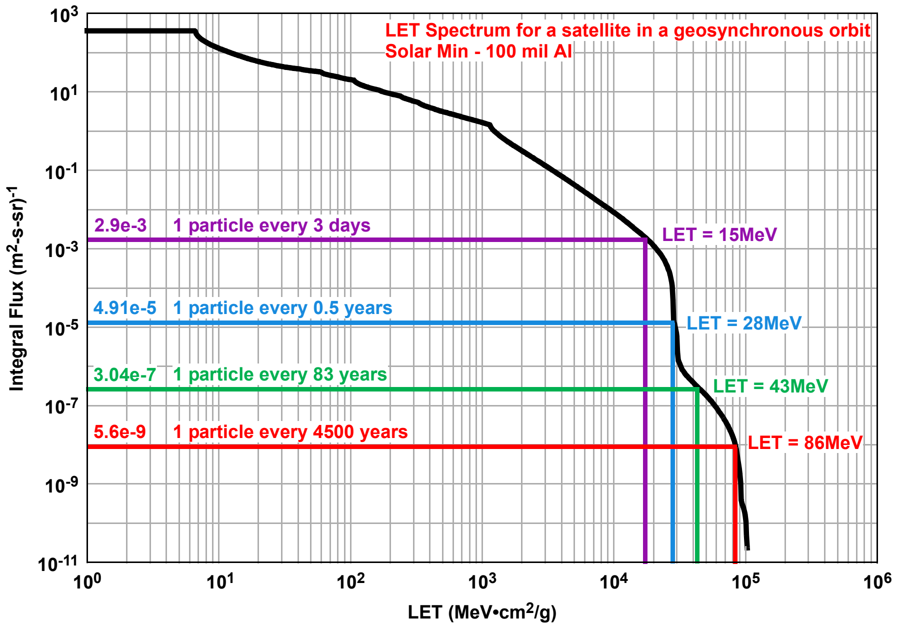

Figure 1. CREME96 LET Spectrum for a Satellite in a Geosynchronous Orbit Assuming Solar Minimum Conditions and 100 mils Al Shielding

In mission terms, we need to determine the particle fluence (or total number of particles in a period of time) at an energy of 43MeV the part would see. Therefore, based on the following equation you can determine how many particles a part would see in a year.

Fluence = Flux * Time

= $(3.04 \times 10^{-11}$ particles/cm^2-s-sr)(60 s/min)(60 min/hr)(24 hr/day)(365.25 days/yr)

= 9.59×10^{-4} particles/cm^2-yr-sr

Statistically speaking, the sensitive volume of the GaN FET ($\leq$1cm^2) in the satellite would see a particle with an LET of ≥ 43MeV approximately once every 83 years in a geosynchronous orbit, compared to the much more common lower energy ions above the knee of the curve. For an ion with an LET of ≥ 86MeV, it is approximately once every 4500 years. While these more energetic ions are not trivial for SEL considerations, they are insignificant for a cumulative event, like current increase. For the higher energy particles, it takes over 292 million years for the parts to see the current increase caused by 1×10^6 ions/cm^2 of ions with an LET ≥ 60MeV and over 4 billion years with 86MeV ions. In a typical 20 year GEO mission, the worst case current increase, on average, is in the picoamps or less for any of the ions that caused the current increase in the exposed parts. The results are summarized in Table 2 for ions with LET ≥ 28MeV. Only the maximum drain-to-source voltages are shown for the 40V and 100V devices, because they did not show any evidence of SEB during testing. However, the 200V device experienced SEB at 200V and LET of ≥ 86MeV, so 160V results are also included.

Table 2. GaN FET Current Increase after 20 Years at 1×10^6 ions/cm^2 (Amps)

Part Type	V_{DSS} (V)	28Mev•cm^2/mg	43Mev•cm^2/mg	60Mev•cm^2/mg	86Mev•cm^2/mg
ISL70020SEH (40V)	40	3.19E-11	2.89E-14	4.93E-14	4.00E-14
ISL70023SEH (100V)	100	1.09E-11	2.14E-13	2.15E-13	1.45E-13
ISL70024SEH (200V)	160	1.09E-11	2.14E-13	2.15E-13	1.45E-13
	200	6.23E-12	1.61E-12	1.05E-12	SEB

2. Conclusion

While SEE testing of the Renesas 40V, 100V, and 200V GaN FETs determined evidence of current increase at energies above 43Mev•cm^2/mg and higher supply voltages, the scarcity of ions of this energy in geosynchronous orbit make the actual increase in current during a typical 20 year mission inconsequential.

3. Revision History

Rev.	Date	Description
1.00	Mar.25.19	Initial release

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