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Radiation hardness estimation in various temperature conditions under radiation impact

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Abstract. The application of the ELDRS conversion model for numerical simulation of the radiation degradation of input bias current in widely used voltage comparator is presented. The recurrence relations for numerical simulations were obtained and used calculations of the estimation of the radiation response of LM111 input bias current in real operation temperature conditions of TechEdSat satellite.

1. Introduction

In space environment the radiation dose rate and temperature can vary drastically and unexpectedly. As it was shown earlier [1], in order to estimate the operation time of electronic equipment under radiation impact with variable dose rate, it is possible to use the averaged value of the dose rate. To predict the operation time correctly it is necessary to take into account only the change in temperature over time for a specified orbit, which the satellite equipment is located on. Using a set of fitting parameters of the conversion model [1] for a particular integrated circuit and a plot of the actual temperature dependence on time for those conditions which the spacecraft will operate in, it is possible to calculate the dependence of the radiation-sensitive parameter degradation on total dose.

In this work we apply the conversion model of enhanced low dose rate sensitivity effect to estimate the dependence of input bias current of LM111 voltage comparator on total dose in real temperature conditions of space environment.

2. Mathematical expressions for numerical simulation

According to basic assumptions of the conversion model we can describe the kinetics of radiation induced positive charge generation in the oxide (Q_{ot}) and the rate of radiation degradation of a radiation sensitive parameter (I_{in}) by following differential equations:

$$\frac{dQ'_{ot}}{dt} = q \cdot K_D \cdot \gamma - \frac{Q'_{ot}}{\tau_D}, \quad (1a)$$

$$\frac{dI_{in}}{dt} = K_S \cdot \gamma + \frac{1}{q} \frac{Q'_{ot}}{\tau_D}, \quad (1b)$$

$$\tau_D(T) = \tau_{D0} \exp\left(\frac{E_A}{kT}\right), \quad (1c)$$

where K_D , K_S , τ_0 and E_A are fitting parameters, γ is dose rate, q is electron charge and $Q'_{ot} = A Q_{ot}$. Expression (1c) represents the Arrhenius law, which we use to describe the dependence of the conversion process rate on temperature.



For numerical calculations expressions (1a) and (1b) can be presented as recurrence relations:

$$Q'_{ot}(t + \Delta t) = \left(qK_D \gamma(t) - \frac{Q'_{ot}(t)}{\tau_D(T)} \right) \cdot \Delta t + Q'_{ot}(t), \quad (2a)$$

$$I_{in}(t + \Delta t) = \left(K_s \gamma(t) + \frac{1}{q} \frac{Q'_{ot}(t)}{\tau_D(T)} \right) \cdot \Delta t + I_{in}(t), \quad (2b)$$

The recurrence relations (2a) and (2b) can be used to calculate values of $Q'_{ot}(t+\Delta t)$ and $I_{in}(t+\Delta t)$ after very short time interval Δt using corresponding values of $Q'_{ot}(t)$ and $I_{in}(t)$ in the beginning of the interval. The value of $\tau_D(T)$ must be calculated for time moment t using expression (1c) and substituted to relations (2a) and (2b). Corresponding temperature value T must be taken at the same time moment. Consequently if we know initial values of Q'_{ot} and I_{in} for $t = 0$ we can calculate this values for any following time moment step-by-step. For correct simulations the duration of Δt must be short enough to consider the temperature and dose rate as constants.

3. Application of the simulation technique for real temperature profile.

In [1] the fitting parameters of the conversion model extracted for LM111 voltage comparator are presented. Using the parameters and information from the on-board temperature sensor of the TechEdSat satellite (Fig. 1, information from the site <https://directory.eoportal.org>), which has low Earth orbit, the numerical simulation of the dependence of input current degradation of bipolar voltage comparator LM111 on time was performed for constant dose rate 1 mrad(SiO₂)/s and a variable temperature.

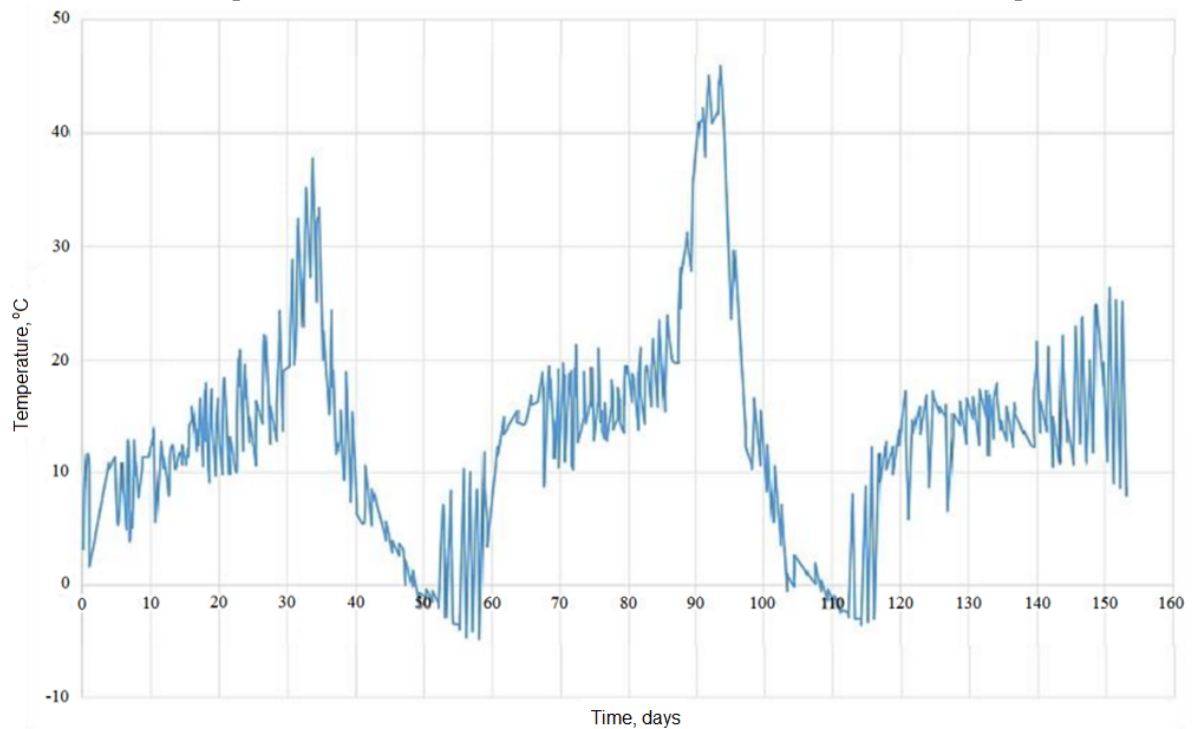


Figure 1. The dependence of the TechEdSat satellite temperature on time for low Earth orbit

For automation of numerical simulation a computer program was developed. The developed program allows to perform a numerical estimation of radiation hardness of integrated circuits for any temperate transient processes. Moreover it enables to perform the updating of the life time estimation for a satellite electronics using real time temperature data.

The numerical estimation of the radiation degradation of the voltage comparator input bias current based on the real time temperature data was performed using relations (2a), (2b) and (1c). The results of performed simulation are presented in Fig. 2. In Fig. 3 the total dose response of the input bias current

is presented for averaged temperature value (22.6°C) and for 25.0°C , which is typical for hardness assurance test procedures, together with real time simulation data from Fig. 2 for comparison.

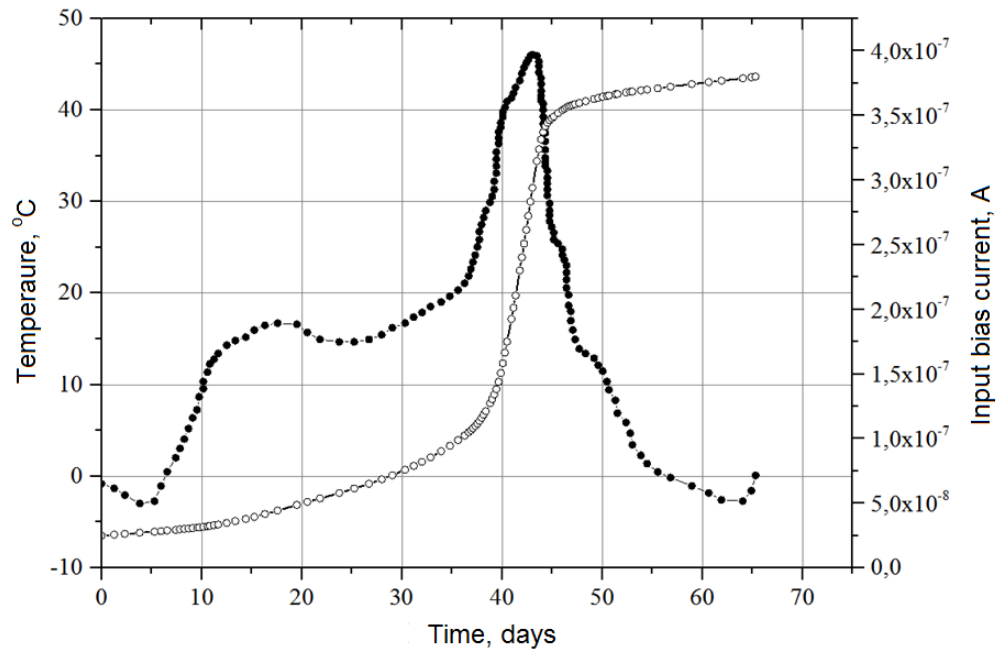


Figure 2. The calculated dependence of the input current degradation of the voltage comparator LM111 on the irradiation time (●), based on the real time dependence of temperature (○) in low-earth orbit for the TechEdSat satellite

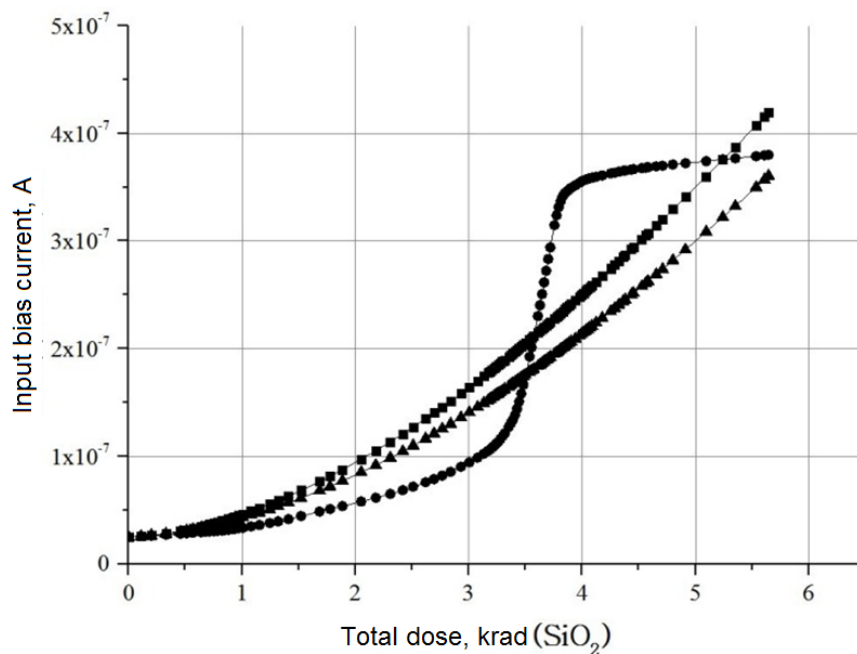


Figure 3. The calculated dependence of the degradation of the input current of the voltage comparator LM111 on total dose at 25°C (■), for complex temperature profile (●) and at an average temperature value (22.6°C) (▲)

The results of the numerical simulation presented in Fig. 2 shows a significant difference between the total dose responses for a constant temperature value and complex temperature profile. It is extremely important to take into account real temperature conditions during space mission.

4. Conclusion

From the simulation results we can see the significant impact of the temperature profile on the degradation rate of the input current of the LM111 voltage comparator. It demonstrates the importance of taking into account the dynamics of the temperature variation when estimating the operation time of the satellite electronic equipment. When using the presented calculation and experimental technique for estimating of the radiation hardness of semiconductor devices, it becomes possible to adjust the prediction of the operation time of electronic devices in the space environment using actual data on the dose rate and operating temperature.

Acknowledgements

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References

- [1] V.S. Pershenkov, A.S. Bakerenkov, A.S. Solomatin, V.V. Belyakov 2013 *Proc. Conf RADECS*. article number 6937456