BOOK of ABSTRACTS

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Radiation behaviour study of linear voltage regulator

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Abstract. For positive low-dropout linear voltage regulator IS-LS1-3.3V it is established that output voltage and consumption current vary slightly in all total investigated ionizing dose interval and do not cause voltage regulator failure. Analytical dependencies of output voltage and consumption current on the total ionizing dose have been obtained.

Keywords: ionizing dose effects, voltage regulator, X-ray irradiation.

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Introduction

For development of industries such as cosmonautics, aircraft engineering, nuclear power, it is necessary to achieve reliable functioning of the electronic components such as voltage regulators that used under radiation conditions [1, 2]. Therefore, with taking into account, the main aim of this work is to study the radiation hardness to the effects of the total ionizing dose of the positive low-dropout linear voltage regulator IS-LS1-3.3V produced by JSC "GRUPPA KREMNY EL" (Bryansk) in framework of import substitution program, using the developed hardware and software complex based on the X-ray research complex.

Materials and Methods

As the object of research was the positive low-dropout linear voltage regulator prototype IS-LS1-3.3V (analogue of LT1963 (JSC "GRUPPA KREMNY EL" (Bryansk)) with output voltage of 3.3 V and made by epitaxial-planar bipolar technology. Studies of the IS-LS1-3.3V voltage regulator for hardness to ionizing radiation by the effects of total ionizing dose were carried out using the developed hardware and software equipment based on an X-ray research complex (XRRC-0401) with calibration at the "Gamma MRX MEPhI" isotope equipment [3].

Results and Discussion

During the radiation experimental study of IS-LS1-3.3V positive low-dropout (LDO) linear voltage regulator prototype the following operation mode was used for XRRC-0401: anode voltage of 70 kV, anode current of 150 μA. The distance from the window of the X-ray source equals of 40 mm and rate of radiation dose exposure equals of 35.3 un./s (un. – the units of the X-ray comparator DRI-0401). In Fig. 1*a* are shown experimental results for voltage regulator obtained during radiation experiment. As can be seen, the output voltage V_{OUT} slowly increase with increasing of total ionizing dose D. It is important to note that output voltage not reaches the lower and upper limit of voltage regulator operation mode (3.135-3.465 V). Thus, at value of total ionizing dose equals of 8×10^3 un. (that is equal of ~282 s (~4.7 minutes)) output voltage V_{OUT} equals of 3.29 V. Further, during increasing of radiation dose exposure the output voltage V_{OUT} increase nonlinearly and at final value of total ionizing dose equals of 1002×10^3 un. (~35430 s (~590.5 minutes)) the output voltage value is 3.33 V ($\Delta V_{OUT}\approx0.04$ V), i.e. in this case the voltage regulator scheme preserves a functional state without failure. As follows from Fig. 1*b* the consumption current I_{cc} varies slightly between 1.59 mA (622×10^3 un.) and 1.25 mA (707×10^3 un.) and reaches 1.246 mA at final value of total ionizing dose equals of 1002×10^3 un. (~35430 s (~590.5 minutes)). It should be noted that a similar results were detected in the similar type of positive LDO linear regulator designed specifically for space applications [4]. From a practical viewpoint, it is important to know for voltage regulator the analytical dependence on the radiation dose. On the basis of above experimental data, analytical dependence of the output voltage V_{OUT} and consumption current I_{cc} on the total ionizing dose D for voltage regulator were calculated.

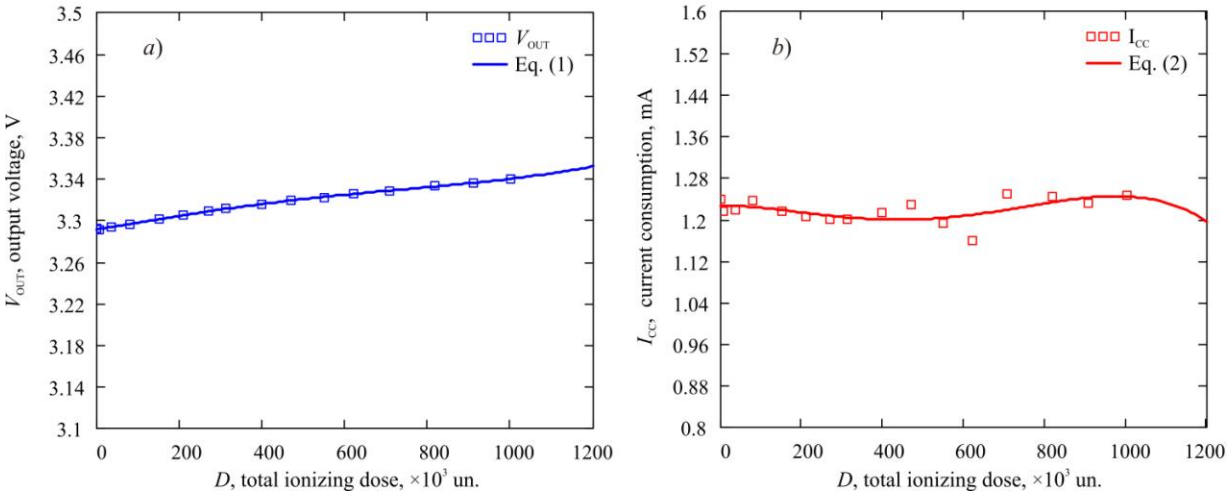

Fig. 1. The experimental (points) and theoretical (lines) data for output voltage dependence V_{OUT} (*a*) and consumption current I_{cc} (*b*) on total ionizing dose *D* for IS-LS1-3.3V voltage regulator.

The analytical dependence of the output voltage V_{OUT} and consumption current I_{cc} on the total ionizing dose *D* for voltage regulator (in active operating mode at input voltage of 24 V and load current of 5 mA) are following:

$$V_{OUT} = 3.204\times10^{-14}D^4 - 4.435\times10^{-11}D^3 - 9.187\times10^{-9}D^2 + 7.041\times10^{-5}D + 3.291, \quad (1)$$

$$I_{cc} = -6.276\times10^{-13}D^4 + 1.183\times10^{-9}D^3 - 5.368\times10^{-7}D^2 - 9.1\times10^{-7}D + 1.226, \quad (2)$$

where *D* – the total ionizing dose (10^3 un.), V_{OUT} – the output voltage (V), I_{cc} – the consumption current (mA).

Conclusion

The radiation hardness to the effects of the total ionizing dose of the positive low-dropout linear voltage regulator IS-LS1-3.3V produced in framework of import substitution program, has been studied using the developed hardware-software complex based on the X-ray research complex. It is established experimentally that output voltage varies slightly from 3.29 up to 3.33 V ($\Delta V_{OUT}\approx1.2\%$) in all total ionizing dose interval and preserves a functional state without failure. It is shown that the consumption current varies slightly between 1.59 mA and 1.25 mA. For voltage regulator have been calculated the analytical dependencies for the output voltage and consumption current on the total ionizing dose.

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