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The radiation hardness of n-p-n type bipolar transistor for voltage regulators

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Abstract. For n-p-n type bipolar transistor for voltage regulator were established characteristics (collector current, base current, common-emitter current gain) depending on total ionizing dose radiation using projected X-ray research complex. The functional dependencies of common-emitter current gain depending on total ionizing dose have been obtained.

Keywords: n-p-n type bipolar transistor, ionizing dose effects, X-ray irradiation.

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Introduction

It is known that investigation of the radiation hardness of voltage regulators to the total ionizing radiation dose effects is important goal for electronics [1]. In particular, as it was established earlier [2], there is possibility increase radiation hardness of voltage regulator using n-p-n type bipolar transistor included as additional element in its scheme. Therefore, study of n-p-n type bipolar transistor characteristics during ionizing radiation using X-ray research complex (XRC) is important scientific task.

Materials and Methods

The n-p-n type bipolar transistor was produced by BiCMOS (Bipolar Complementary Metal Oxide Semiconductor) technology as element of some linear positive voltage regulator [2]. Investigation of n-p-n type bipolar transistor characteristics during ionizing radiation has been carried out using the earlier developed X-ray research complex. The functioning algorithm complex and the scheme of the developed complex are described in detail [3]. In particular, the characteristics study of n-p-n type bipolar transistor under radiation conditions was performed at following operating mode of XRC: anode voltage – 70 kV, anode current – 150 μA, the rate of radiation dose accumulation was 150 un./s (un. – units of the DRI-0401 comparator including in XRC), distance between the X-ray tube window and the sample – 25 mm.

Results and Discussion

The n-p-n type bipolar transistor was connected according to the typical scheme for measuring of the collector current, base current and common-emitter gain. Transistor was operated under radiation in next electrical mode: the collector-emitter voltage is 16 V (Fluke 8845A multimeter) and two base currents values of 100 nA and 1 μA (Keithley 6485 picoamperemeter), programmable power source is Rigol DP832. In Fig. 1 are presented the collector current I_C, base current I_B and common-emitter current gain β depending on total ionizing dose D for investigated n-p-n type bipolar transistor. As follows from Fig. 1 the value of collector current decrease with increasing of total ionizing dose for both base currents (100 nA and 1 μA). The transistor's base current I_B (initial base current values: 100 nA and 1 μA) lightly increase as total ionizing dose increase. The common-emitter current gain β for transistor at base current of 100 nA (common-emitter of 16 V) at first increase from 71, then reach the maximal value of 101 at dose of 24×10^3 un. and further decrease up to 9 at final dose of 800×10^3 un. In case when the base current is 1 μA (common-emitter voltage is 16 V) common-emitter current gain decrease from 116 up to 14 at dose of 800×10^3 un. For engineers and developers of voltage regulators, that included same n-p-n type bipolar transistor, that work under radiation conditions it is important to know the analytical dependence of common-emitter current gain its transistor from radiation dose for calculation of addition resistance of compensation resistor in the feedback circuit for preventing of output voltage changing [2]. Therefore, based on regression

analyses methods, the analytical dependencies of the common-emitter gain β on the total ionizing dose D for n-p-n bipolar transistor (base current is 100 nA (Eq. 1) and 1 μA (Eq. 2) consequently, collector-emitter voltage V_{CE}=16 V) are following form:

$$\beta(D) = -1.982\times10^{-7}\times D^3 + 4.278\times10^{-4}\times D^2 - 30.5\times10^{-2}\times D + 83.463, \quad (1)$$

$$\beta(D) = -3.101\times10^{-7}\times D^3 + 6.427\times10^{-4}\times D^2 - 43.8\times10^{-2}\times D + 117.075, \quad (2)$$

where β – the common-emitter gain, D – the total ionizing dose (10^3 un.).

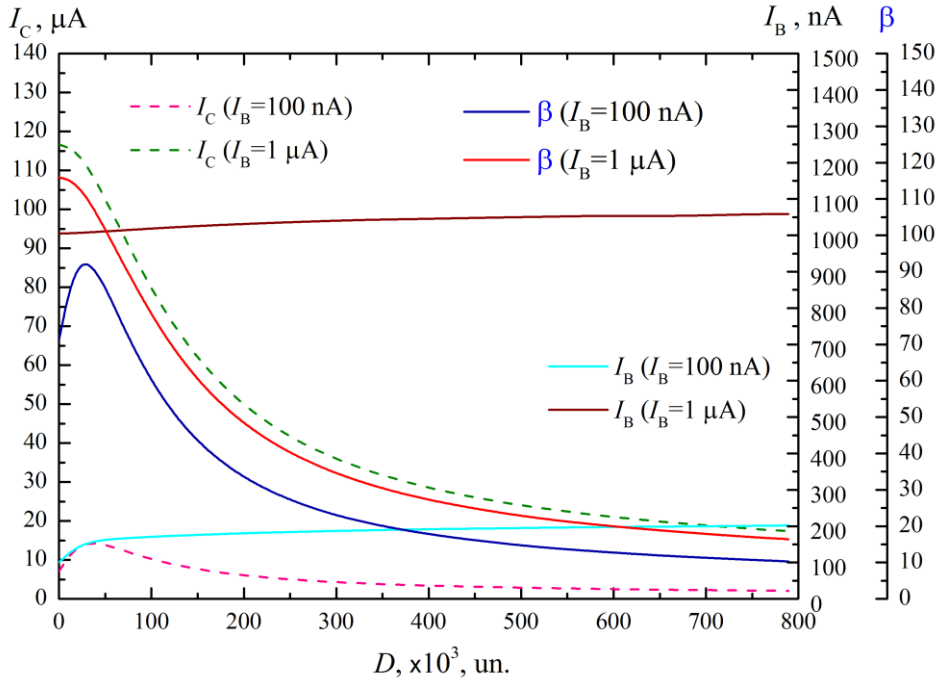

Fig. 1. The collector current I_C, base current I_B and common-emitter current gain β dependencies on total ionizing dose D for n-p-n type bipolar transistor (collector-emitter voltage V_{CE}=16 V).

Conclusion

The radiation hardness for n-p-n type bipolar transistor was studied using X-ray research complex. It is obtained dependencies of collector current, base current and common-emitter current gain from total ionizing dose radiation. For common-emitter current gain bipolar transistor's were established analytical dependencies on total ionizing dose necessary for improvement voltage regulators scheme functioning under radiation conditions.

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