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Method for increasing of the voltage regulator radiation hardness

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Abstract. For positive low-dropout linear voltage regulator the additional circuit elements have been developed in the output stage of the for positive linear voltage regulator, forming compensatory feedback and making it possible to increase voltage regulator radiation hardness.

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

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Introduction

Today, the one of the main task is to increase the radiation hardness of electronic components to the effects of ionizing radiation [1, 2]. Therefore, the urgent question is to study a methods for increasing radiation hardness, especially, studying the response of individual elements of a linear voltage regulator IS-LS3-5V microcircuit, produced by JSC "GRUPPA KREMNY EL" (Bryansk) in framework of import substitution program, to total ionizing dose of ionizing radiation, using the developed hardware and software complex based on the X-ray research complex.

Materials and Methods

The positive low-dropout linear voltage regulator prototype IS-LS3-5V (analogue of LM2937 type) produced by JSC "GRUPPA KREMNY EL" (Bryansk) with output voltage of 5 V and made by epitaxial-planar bipolar technology. Investigation of the IS-LS3-5V 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

Additional circuit elements have been developed in the output stage of the linear voltage regulator, forming compensatory feedback, as a result of which the output voltage parameter of the voltage regulator remains within the limits established by the technical requirements at large values of the total ionizing dose [4]. This method can be implemented both at the stage of manufacturing a microcircuit chip, and as an external wiring diagram when using already produced serial products. Fig. 1*a* shows part of the electrical circuit of the IS-LS3-5V positive voltage regulator integrated microcircuit where the measurements were carried out.

In a known linear voltage regulator, the base of an additional n-p-n transistor is connected to the second inverted input of the operational amplifier, the collector of which is connected to the positive bus of the regulator, and the emitter is connected through the current generator to the negative bus of the regulator and a resistor is connected between the feedback pin and the second input of the operational amplifier, the value of which is determined by the formula:

$$R = \beta \Delta U_{\mathrm{REF}} / I_{\mathrm{G}}, \tag{1}$$

where β – the gain with the common emitter of the additional transistor after exposure to radiation; ΔU_{REF} – change in reference voltage from the nominal voltage after exposure to radiation; I_{G} – the magnitude of the generator current in the emitter circuit of the additional transistor. When exposed to radiation, the magnitude of the output voltage of the reference voltage source increases. An additional n-p-n transistor is a radiation dose sensor. The higher the radiation dose, the lower its gain in a common emitter circuit. At doses less than 200×10^3 un. (un. – the units of the X-ray comparator DRI-0401), the gain of the n-p-n transistor changes slightly. Since the emitter current of the additional n-p-n transistor is set by the current generator and remains stable, when exposed to ionizing radiation, the current in the base circuit increases, the voltage drop across the resistor in the feedback circuit also increases, which leads to an increase in the potential at the inverted input of the operational amplifier. This causes the operational amplifier's output current to decrease, the output transistor to turn off, and the drain-to-source voltage drop to increase, thereby compensating for the drift of the output voltage due to the effect of ionizing radiation on the reference voltage source. In our case the calculated by equation (1) value of resistor R in the feedback circuit is 90 kΩ. In Fig. 1*b* presents the results of studies on the radiation hardness of voltage regulator without a compensation circuit (solid line) and using the method discussed above (dashed-line). As can be seen from Fig. 1*b*, the output voltage of the modified voltage regulator integrated circuit remains almost constant.

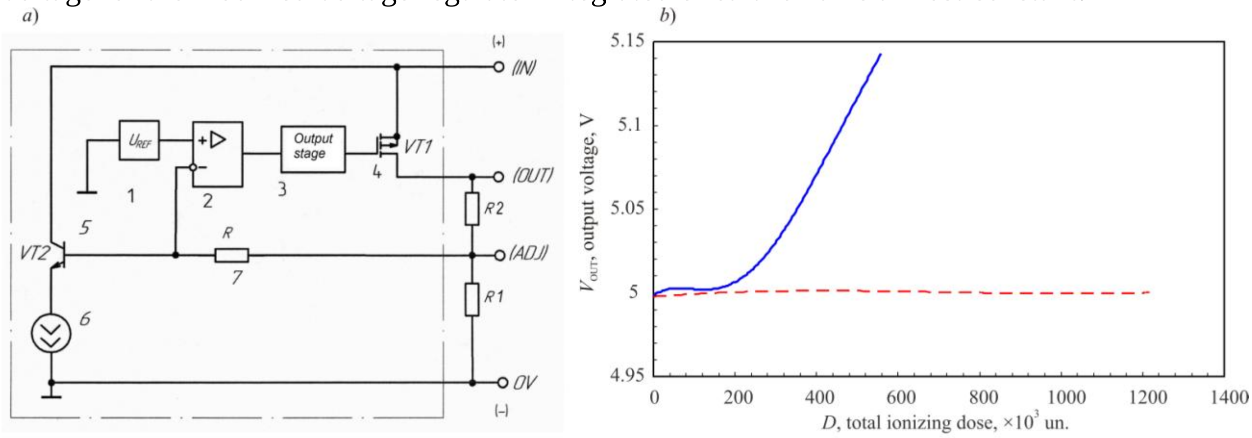

Fig. 1. (*a*) Diagram of positive voltage regulator IS-LS3-5V: 1 – reference voltage source at the bandgap width; 2 – operational amplifier; 3 – output stage; 4 – output transistor; 5 – additional n-p-n transistor; 6 – current generator; 7 – additional resistor; 0V – positive bus; ADJ – feedback pin for adjusting the stabilization voltage; OUT – output of the voltage regulator; IN – positive bus; R1 and R2 –the stabilization voltage settings divider; (*b*) The output voltage V_{OUT} dependence on total ionizing dose D for IS-LS3-5V voltage regulator: solid line – original voltage regulator integrated circuit, dashed-line – modified voltage regulator integrated circuit.

Conclusion

The method of radiation hardness increasing to the positive low-dropout linear voltage regulator prototype IS-LS3-5V (produced by JSC "GRUPPA KREMNY EL" (Bryansk)) with output voltage of 5 V has been developed. It is shown that additional circuit elements in the output stage of the linear voltage regulator form compensatory feedback and make it possible to increase its radiation hardness.

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REFERENCES

1. **Gaul S. J., Vonno N., Voldman S. H., Morris W. H.**, Integrated Circuit Design for Radiation Environments, Wiley & Sons, Chichester, 2020.

2. **Volovich G. I.,** Circuit Technique of Analog and Analog-digital Electronic Devices, DMK Press, Moscow, 2018.

3. JSC "Specialized electronic systems" (SPELS). URL: http://www.spels.ru. Accessed Mar. 30, 2024.

4. Patent RU 219091 U1, 2023. Authors: Derbunov I.V., Bryukhno N.A., Dantsev O.O., Kulchenkov E.A.