Conference materials
UDC 621.382.2/.3; 537.312.54
DOI: https://doi.org/10.18721/JPM.173.138

# 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 voltage regulator, forming compensatory feedback and making it possible to increase voltage regulator radiation hardness.

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

**Funding:** This study was supported by the Russian Ministry of Science and High Education (agreement with the Russian Ministry of Science and High Education of 9 February 2023 No. 075-11-2023-008) using state support measures provided by the Russian Federation Government's Decree of 9 April, 2010 No. 218.

**Citation:** Pilipenko K.S., Kulchenkov E.A., Rybalka S.B., Demidov A.A., Method for increasing of the voltage regulator radiation hardness, St. Petersburg State Polytechnical University Journal. Physics and Mathematics. 17 (3.1) (2024) 191–194. DOI: https://doi.org/10.18721/JPM.173.138



Материалы конференции
УДК 621.382.2/.3; 537.312.54
DOI: https://doi.org/10.18721/JPM.173.138

# Метод для повышения радиационной стойкости стабилизатора напряжения

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**Аннотация.** Для линейного стабилизатора напряжения положительной полярности с низким падением напряжения IS-LS3-5V разработаны дополнительные элементы схемы выходного каскада стабилизатора напряжения, формирующие компенсационную обратную связь и позволяющие повысить радиационную стойкость стабилизатора напряжения.

**Ключевые слова:** стабилизатор напряжения, эффекты поглощенной дозы, рентгеновское излучение

**Финансирование:** Работа выполнена при финансовой поддержке Министерства науки и высшего образования РФ (соглашение с Министерством науки и высшего образования от 9 февраля 2023 г. № 075-11-2023-008) с использованием мер государственной поддержки, предусмотренных постановлением Правительства РФ от 9 апреля 2010 г. № 218.

**Ссылка при цитировании:** Пилипенко К.С., Кульченков Е.А., Рыбалка С.Б., Демидов А.А. Метод для повышения радиационной стойкости стабилизатора напряжения // Научно-технические ведомости СПбГПУ. Физико-математические науки. 2024. Т. 17. № 3.1. С. 191–194. DOI: https://doi.org/10.18721/JPM.173.138

## 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 produced by JSC “GRUPPA KREMNY EL” (analogue of LM2937 type [3]) 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 (JSC “Specialized electronic systems” (SPELS) [4, 5]).

## Results and Discussion

For increasing of voltage regulator's radiation hardness the additional circuit elements have been previously 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 [6]. 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 shows part of the electrical circuit of the IS-LS3-5V positive voltage regulator integrated circuit with additional elements where then 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

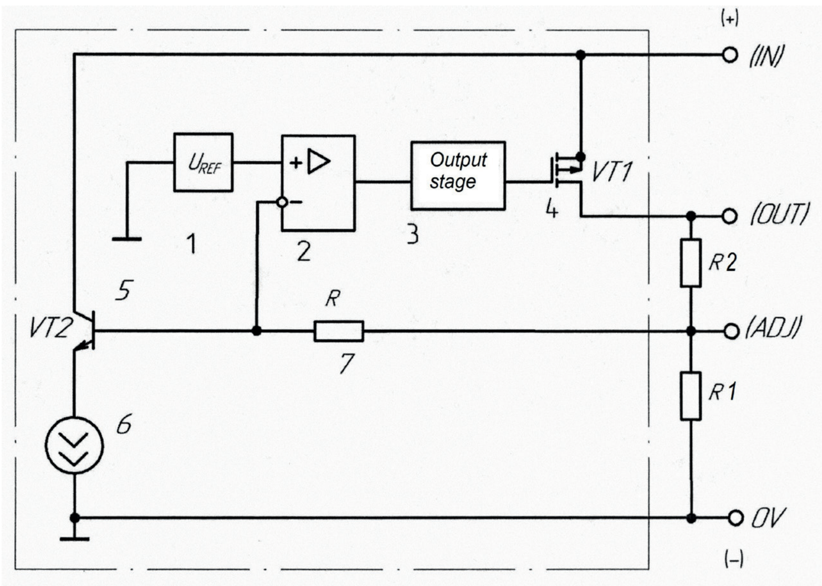


Fig. 1. Diagram of positive voltage regulator IS-LS3-5V: *1* — reference voltage source at the bandgap width; *2* — operational amplifier; *3* — output stage; *4* — output transistor; *5* — additional n-p-n transistor; *6* — current generator; *7* — additional resistor; 0V — positive bus; ADJ — feedback pin for adjusting the stabilization voltage; OUT — output of the voltage regulator; IN — positive bus; R1 and R2 — the stabilization voltage settings divider

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:

$$R = \beta \Delta U_{REF} / I_G, \quad (1)$$

where β – the gain with the common emitter of the additional transistor after exposure to radiation; $\Delta U_{REF}$ – 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 $200\times10^3$ un. (un. – the units of XRRC-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. 2 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).

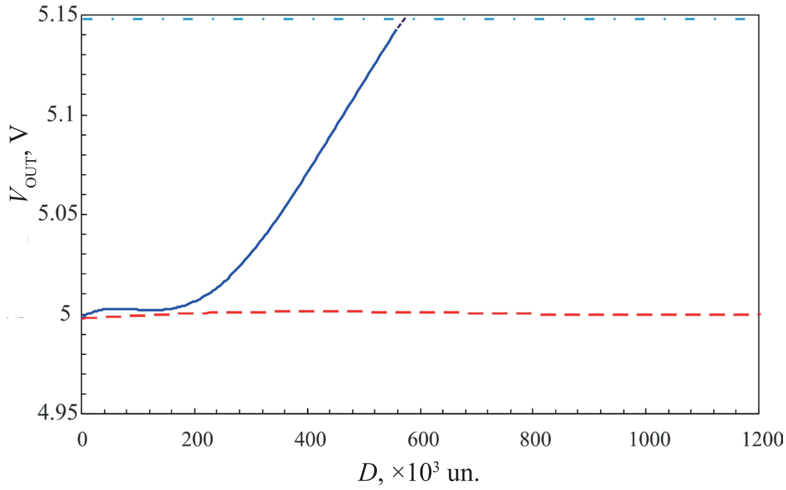


Fig. 2. The output voltage $V_{OUT}$ dependence on total ionizing dose $D$ for IS-LS3-5V voltage regulator: solid line – original voltage regulator integrated circuit, dashed-line – modified voltage regulator integrated circuit with additional circuit elements (dash-dot line – the upper limit of voltage regulator operation mode)

As can be seen from Fig. 2, the output voltage of the modified voltage regulator integrated circuit remains almost constant. Because of this, the output voltage $V_{OUT}$ for nonmodified voltage regulator increase with increasing of total ionizing dose and reaches the upper limit of voltage regulator operation mode (5.15 V) at total ionizing dose equals of ~$560\times10^3$ un. Therefore, using the above-mentioned additional circuit elements in the output stage of the linear voltage regulator leads to increasing of its radiation hardness more than two times.

**Conclusion**

The method of radiation hardness increasing to the positive low-dropout linear voltage regulator IS-LS3-5V (produced by JSC "GRUPPA KREMNY EL") 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.

**Acknowledgments**

The results of the Research and Development have been achieved during the implementation of the project “Integrated microcircuits of analog signal converters in metal-polymeric package of various types: development and mastering of technology, replacement of imported analogs and organization of serial production” (agreement with the Russian Ministry of Science and High Education of 9 February 2023 No. 075-11-2023-008) using state support measures provided by the Russian Federation Government's Decree of 9 April, 2010 No. 218.

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*Received 11.07.2024. Approved after reviewing 31.07.2024. Accepted 01.08.2024.*