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HIGH- LINEAR DC AMPLIFIERS WITH SYMMETRIC STRUCTURE FOR MEASUREMENTS CONTROL SYSTEM.

Determining component of analog circuit engineering, is amplifier, separate niche among these devices is occupied by DC amplifiers(DCA), being the basic component of operational amplifiers, for analog and hybrid computers and measuring information systems [1]. Historically, first DCA were constructed on vacuum tubes [2]. As a results of application of approaches and principles of vacuum tube amplifiers on transistor- based amplifiers integrated transistor-based circuits of DCA, appeared in 60`s and 70`s resembled vacuum tube circuits.This considerably limited the achievements of potential possibilities within the limits of dynamic and static characteristics, since it did not allow to use frequency properties of transistors up to limiting frequency , and restricted the linearity of transfer characteristic and a number of other parameters.

Key words: *symmetric structure, direct current amplifier.*

A great number of modern DC amplifiers use mainly single channel asymmetric structure with differential amplifying stage at the input and two cycle symmetric stage at the output, providing principle of voltage amplification and transformation[3]. The advantages of such approach are functional versatility of the circuits, enabling to use them in different devices (operational amplifiers, buffer devices, devices for sampling – storage of analog signals, comparators, etc). However, differential stage – based amplifiers with single – channel structure have some disadvantages: low rate of initial signal increase, considerable coefficient of non – linear distortions, especially in case of increase of input signal frequency, asymmetry of output signal while operation by rectangular bipolar input pulse.

However, it should be noted, that as far back as in 70s two cycle symmetrical current amplifiers were constructed. But they had some restrictions, since they had a limited number (1 or 2) of amplifying stages, low linearity and small gain factor. One of the reasons of such restriction was that in the given circuits with multistage

Structure (2 or 3) it is difficult to set operation mode by direct current. That is why, it was not possible to make use of the advantages, provided by two – cycle direct current amplifiers with symmetrical structure. Therefore, the problem of construction of two – cycle symmetrical direct current amplifiers with increased linearity of transfer characteristic remains actual. The author suggests performing the construction of amplifying devices on the base of two – cycle symmetric structures of DCA, where the problem of operating point setting is overcome using two directional current reflectors.

The advantages of such approach are high linearity of statistic transfer characteristic, increased speed and symmetric reaction on input rectangular bipolar pulse [4].

In spite of a number of practical realizations, of difference versions of such amplifiers, protected by the Patents of the USSR and Ukraine, the analysis of transfer characteristic of such DCA is not complete due to the lack of corresponding analytical dependences.

The aim of the paper – considers circuit realizations of DCA with symmetrical structure, analyze their advantages as compared with conventional asymmetric structure.

Problem solutions

We will consider main peculiarities of construction of amplifying devices with symmetric structure. Depending on construction of input stage, symmetric DCA can be divided into two main groups:

1. devices with selfcomplementary circuit with common base;
2. devices with hybrid circuit and common collector.

Let us consider simplified scheme of direct current amplifier with symmetric structure, shown in

Fig 1.

It can be referred to the first group of symmetric DCA circuits

Two – cycle symmetric DCA consists of input stage, built on T 1 and T 2 transistor, connected by means of self complementary circuit with common base, and intermediate amplifying stages on the base of T 9 and T 10 transistors connected with common emitter using the circuit. For setting and balancing of direct current mode of intermediate stages, two – directional current reflector on transistors T 3 and T 5, T 6 and T 7, T 4 and T 8 as well as two transistors T 10, T 11 in diode connection is introduced in the circuit.

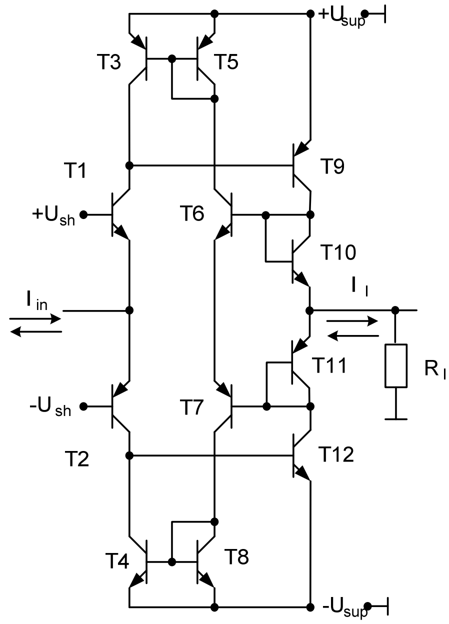

Fig 1 Simplified schematic diagram of two – cycle symmetric DCA.

Total current transfer ratio is described by the formula:

$$K_i(I_{in}) \cong \frac{\beta_0^{(12)}\alpha_2 + \beta_0^{(9)}\alpha_1}{2} + \frac{\beta_1^{(12)}\alpha_2 + \beta_1^{(9)}\alpha_1}{2}\Delta I_{in} + \frac{\beta_2^{(12)}\alpha_2 + \beta_2^{(9)}\alpha_1}{2}\Delta I_{in}^2$$

Fig 2 shows simplified schematic diagram of direct current amplifier with symmetric structure, belonging to the second group.

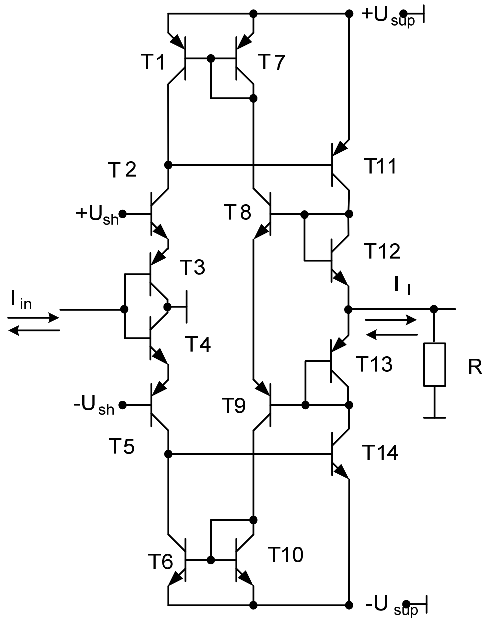

Fig 2 Simplified schematic diagram of two – cycle symmetric DCA by hybrid circuit with common collector.

The peculiar feature of considered circuit is its input amplifying stage on T 3 and T 4 transistors, constructed on the base of hybrid circuit with common collector. In the same way, as in the previous circuit, two – directional current reflector is used for setting direct current mode on transistor T1 and T7, T 6 and T 10, T 8 and T 9, as well as T 12 and T 13 in diode connection. The advantages of direct current amplifiers with symmetrical structure is symmetric reaction on rectangular bipolar pulse, high rate of output signal increase.

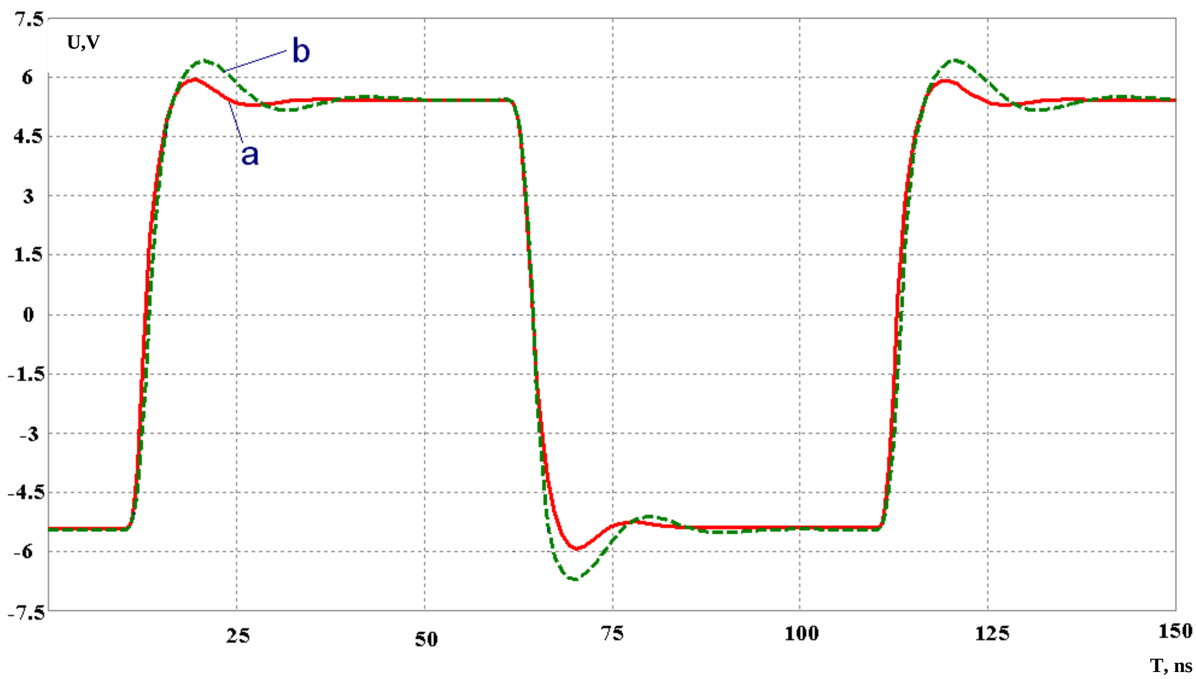

Fig 3.Transfer characteristic of DCA with symmetric structure:
a). circuit 1 b) circuit 2.

High linearity of transfer characteristic is achieved due to the usage of symmetric structure of direct current amplifiers. Fig 4 shows typical error of transfer characteristic of DCA.

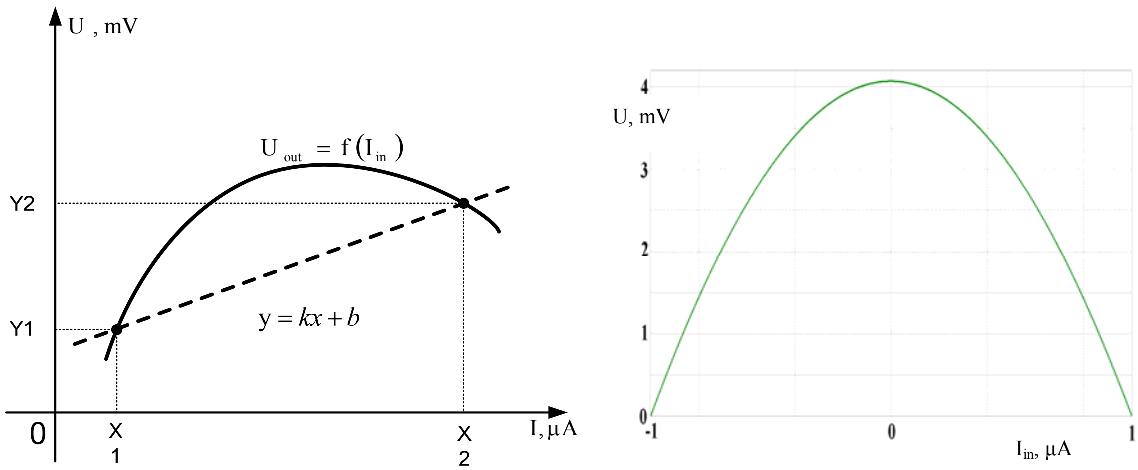

Fig 4. Graphs of statistic transfer characteristic:
a). schematic; b). two – cycle symmetric DCA in the range of ±µA.

It should be noted, that in spite of the lack of output stage, that would increase load – carrying capacity of preamplifying circuit of the stage, linearity errors are rather law. At the same time additional introduction of output stage allows to increase total transfer coefficient.

For area with small density of signals we will have the following increments at load resistor for two – cycle symmetric DCA [5].

$$\Delta I_{н} = \frac{\beta_{12}\alpha_2 + \beta_9\alpha_1}{2} I_{вх} + (\beta_{12}\alpha_2 - \beta_9\alpha_1)\left(\sqrt{\frac{I_{вх}^2}{4} + I_0^2} - I_0\right),$$

where ΔI_l – current, flowing across the load, I_{in} – input current, I_0 – zero shift, β_9 and β_{12} – differential current gain factors of corresponding transistors in the circuit with common emitter, β_1 and β_2 – parameters of corresponding transistors in the circuit with common base [4].

One more advantage as compared with asymmetric structures is low coefficient of linear distortions. Coefficient of non – linear distortions in analytical form for two – cycle DCA with symmetric structure is introduced [5]:

$$\upsilon = \left| \frac{\left(-\frac{\overline{\beta_1}}{2} + \overline{\beta_2} I_0 \right) I_{вх}}{\overline{\beta_0} + \overline{\beta_1} I_0 - \frac{\overline{\beta_2}}{2} I_{вх}^2} \right|$$

The application of the symmetric structure and two – directional current reflectors in amplifying stages allows to construct DCA with high gain factor: 100 and higher.

Conclusions

1. Analytical expressions for the gain factor of input stage, stages of prior amplification and initial stage of two – cycle DCA are presented. They allow to estimate the value of these factors, using differential current gain factors of p – n – p and n- p- n transistors.
2. The influence of current gain factors of n – p – n and p – n – p transistors on the coefficient for non – liner distortions in the range of input signal frequencies is shown.
3. Practical circuits of real DCA are suggested, the analyses of their gain factors values is performed. It should be noted that two cycle symmetric structures have low coefficient of non-linear distortions at rather high current gain factor (10^2-10^3) and in some cases they can be used without feed back.

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