DOI: https://doi.org/10.37547/mesmj-V4-I2-14 Pages: 93-98

MENTAL ENLIGHTENMENT SCIENTIFIC – METHODOLOGICAL JOURNAL

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http://mentaljournal-jspu.uz/index.php/mesmj/index

FEATURES AMPLIFYING PROPERTIES OF A FIELD EFFECT TRANSISTOR IN THE CIRCUIT WITH DYNAMIC LOAD

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ABOUT ARTICLE

Key words: field-effect transistor; dynamic load; gain; bipolar connection mode.

Received: 01.04.23
Accepted: 03.04.23
Published: 05.04.23

Abstract: In the field-effect transistor with dynamic load at bipolar connection mode, when an electric field is applied to the drain-gate junction (source connected to the gate) can be obtained two orders of magnitude higher gain in contrast to the known circuit with a common source. The closer the operating point to the pinch-off of the channel, the higher the voltage gain. In this case the maximum values of drain current corresponding to the light currents of discrete transistors by forward voltage vary in a quadratic law and they are a continuation of the transfer characteristics in dark, which makes possible their use as photodetectors in electronic circuits. In the series-connected field-effect transistors modulated junction, as in the two-barrier structures, controls the parameters of the second junction due to redistribution of the voltage applied from an external power source.

INTRODUCTION

Audio frequency amplifiers are the most common types of amplifiers. In them, the main problem is to eliminate the asymmetry of the amplified useful signal, especially when the signal level is reduced. To improve the amplifying properties of low-frequency amplifiers, field-effect transistors in the cascade switching mode are more often used, as well as methods of direct (composite) connection of two field-effect transistors, which make it possible to obtain a combination of the best properties of field-effect and bipolar transistors [1, 2]. Known works are mainly devoted to the development of amplifiers with different switching modes that provide the required parameters of the amplifier stage [3, 4, 5]. However, a limited number of works have been devoted to the problems of eliminating distortions and increasing the gain.

This paper presents the results of a study of a field effect transistor in a bipolar switching mode with a dynamic load, when an electric field is applied to the drain-gate junction (the source is connected to the gate), as an alternating signal amplifier.

MATERIALS AND METHODS

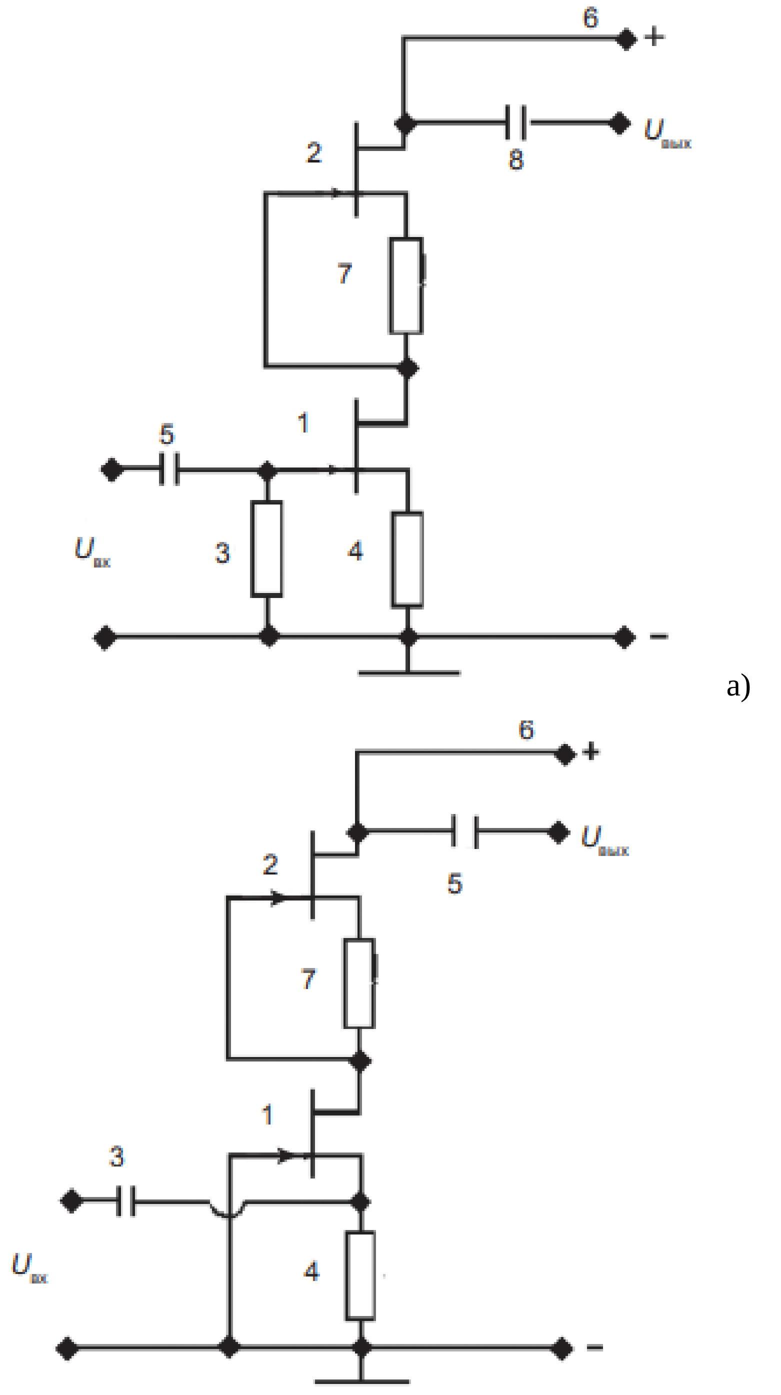
Study field transistors. The field-effect transistors with a control p-n junction selected for research were obtained on p+-type silicon substrates with a carrier concentration of 1 1019 cm–3 and a thickness of 200 μm. An n-type channel is formed by epitaxial growth of a film with a carrier concentration of 2 × 1015 cm–3 and a thickness of 1–2 μm. They are analogues of the epitaxial-planar field-effect transistor of the KP303 type [6]. The choice of the design of a field-effect transistor of the KP303 type is due to the fact that they have small capacitances, and the cut-off voltages lie in a wide voltage range, from 0.5 to 2.5 V.

RESULT AND DISCUSSION

Amplification properties of the field transistor with dynamic load. To increase the channel modulation depth, as was shown in [7], it is advisable to apply the operating voltage not to the channel, Fig. 1a, but to the drain-gate junction, when the source is connected to the gate through a resistor, fig. 1b.

In this case, simultaneous longitudinal and transverse modulation of the channel by a layer of space charge is carried out and the output dynamic resistance increases, leading to a pronounced saturation of the drain current.

In this circuit, the constant voltage URz - u, falling on the resistance, sets the drain current, and the input signal from the G3-109 audio signal generator is fed through the capacitor to the source (Fig. 1b). The amplified output signal is taken from the dynamic resistance, the value of which depends on the amplitude of the signal at the drain of the working transistor. For direct current, the channels of both transistors are connected in series, which leads to greater modulation of the channel from the input signal compared to that in a common-source circuit. In the proposed channel modulation principle (Fig. 1b), the gain (3500) for small signals (1 mV) is obtained by two orders of magnitude higher than in classical common-source switching methods (Fig. 1a) [3, 4]. For a given frequency range of 400 Hz and an input signal of 2 mV, with an increase in the resistance value connecting the gate to the source from 0.43 kΩ to 40 kΩ, the gain of the sinusoidal signal increased from 400 to 3500 (Table 1), which is two orders of magnitude higher compared to than (Kus = 5) in an economical three-stage amplifier [3].



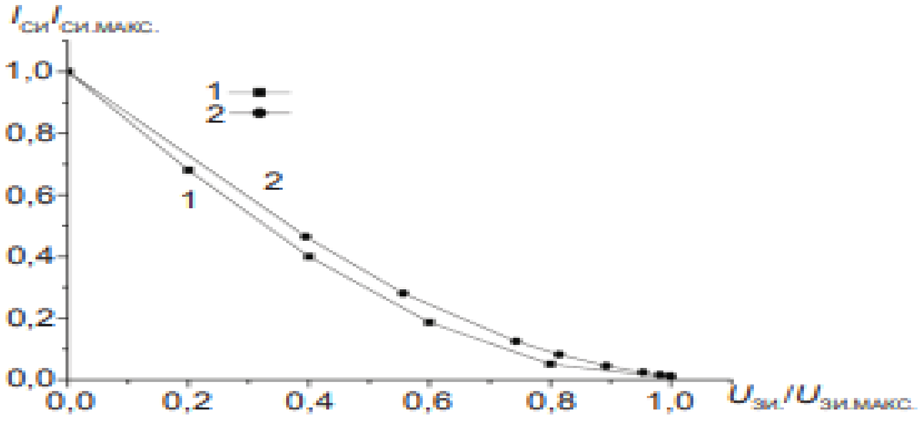
Rice. 1. Amplifier circuits with dynamic loading.

Table 1

Data of the output signal and gain at various resistances connecting the source to the gate.

F = 400 Гц, Uвх = 2 mВ								
$R_{и-з}$ кОм	0,43	1,0	3,0	5,0	10	20	30	40
$U_{зи}$, В	0,377	0,531	0,710	0,778	0,853	0,911	0,938	0,955
Iси, мкА	878	531	236	155	85	45,5	31	23
$U_{вых}$, В	0,8	1,0	2,0	2,4	3,2	5,0	6,0	7,0
$K_{ус}$	400	500	1000	1200	1800	2500	3000	3500

The observed increase in the gain is due to an increase in the thickness of the depleted layer of the source part due to an increase in the voltage taken from the resistor, which leads to an increase in the modulation depth of the base region. In this case, as the resistance value increases, the voltage at the gate-source junction increases from -0.377 V to -0.955 V, and the drain current decreases from 878 μA to 23 μA. In this case, the transfer characteristic is linearized, that is, the steepness increases at low drain currents, Fig. 2, curve 2, resulting in more gain than the common-source circuit.



Rice. 2. Transfer characteristics in a normalized form for transistor and bipolar switching of a field-effect transistor

High gain effect mechanism. Studies have shown that the creation of a difference in the resistance values of the gate-source transition of an amplifying or dynamic transistor leads to a decrease in the output signal. So, when the resistance of a dynamic transistor decreases, the output signal decreases, followed by an increase in the cutoff of the upper half of the output signal, and as it increases, the output signal also decreases, followed by an increase in the cutoff of the lower half of the output signal pulse. In the case of equal resistances of the formed bipolar structures, the current of the first transistor will be equal to the current of the second transistor $I^1_{SI} \approx I^2_{SI}$, and relative to this current value, we have a change in the drain current ΔI^1_{SI}, leading to the formation of an output voltage. However, resistance imbalance leads to the fact that a two-terminal with increased resistance begins to limit the current of a two-terminal with less resistance, which leads both to a decrease in the output signal and to distortion of its shape.

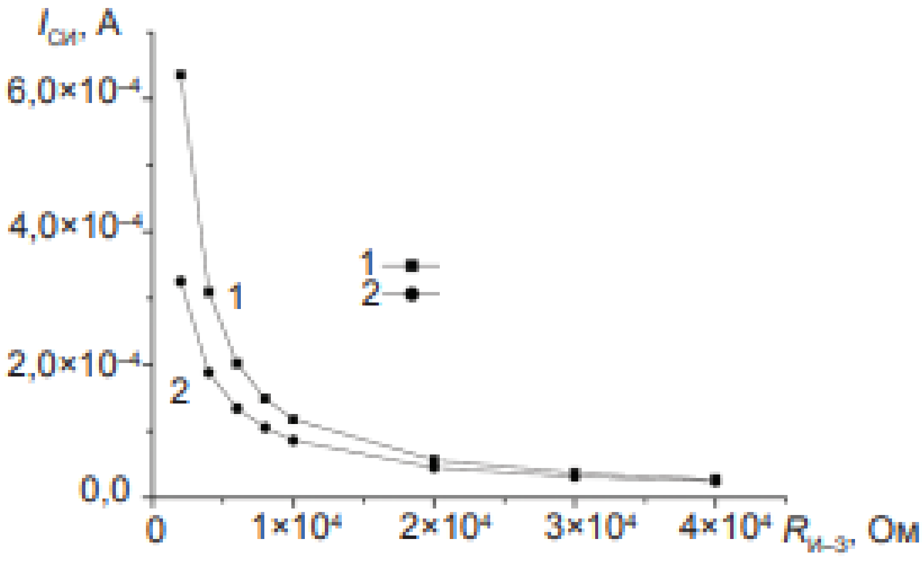
Discussion of the obtained results. As shown in fig. 1b in the proposed amplifier circuit with a dynamic load, the same current passes through the channels and biasing resistors. Therefore, as the value of resistance R_{i-z} increases, connecting the gate to the source, the voltage falling on it will increase, which will lead to a decrease in the drain current [3-7]

$$I_{си} = \frac{U_{отс}}{R_{и-з}} + \frac{U_{отс}^2}{2R_{и-з}^2 I_{си.макс}}\left(1 - \sqrt{\frac{4I_{си.макс}R_{и-з}}{U_{отс}} + 1}\right)$$

and, accordingly, we will have a voltage falling on the source-gate resistance R_{i-z}

$$U_{зи} = I_{си} R_{и-з}.$$

The experimental dependences of the drain current on the value of the resistance Rand –z and the curves calculated by formula (1) take close values as the economy mode approaches, fig. 3.



Rice. 3. Dependences of the drain current on the source-gate biasing resistance

Note that the voltage at the source-gate junction required to completely block the channel can be taken equal to the cutoff voltage. According to experimental data, its value is 1.64 V. For a voltage of 1.64 V, the calculation according to formula (3) gives a depleted layer thickness of 1.04 µm, and for an incident voltage of 0.9 V, 1.01 µm is obtained. At the same time, at the source part, 0.03 µm remains uncovered with the initial depletion thickness W0 = 0.65 µm determined by the diffusion potential.

That is, for a given signal ΔU, modulating the remainder of the 0.03 µm thickness will be more efficient than 0.35 µm for zero gate bias.

Thus, it has been experimentally shown that on a field-effect transistor in the bipolar switching mode with a dynamic load on the field-effect transistor, it is possible to eliminate useful signal distortion and obtain a high voltage gain by selecting source-gate biasing resistances [8-11].

CONCLUSION

In a FET in a bipolar turn-on mode, when an electric field is applied to the drain-gate junction (the source is connected to the gate), you can get a high gain (two orders of magnitude more) in contrast to transistor turn-on. It has been experimentally established that the optimal choice for obtaining an output signal without distortion is the choice of the same potential at the source-gate junction for the main and load transistors. The closer the operating point is to the channel cutoff mode, the higher the voltage gain.

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