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CONTROLLING MECHANISMS OF SPACE-CHARGE REGION IN COMPOUND FIELD-EFFECT TRANSISTORS

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ABSTRACT

In the compound transistor being investigated, to prevent the failure of the direct-biased transistor, resistors are connected to their gates, the value of which is equal to the resistance of the locked gate. The gate transistor is in the micro mode, that is, its drain current is equal to the gate current of the drain transistor. In this case, the drain transistor operates in the forward bias mode.

KEYWORDS: field-effect transistors, compound transistor, channel modulation processes, *p*-*n*-junction.

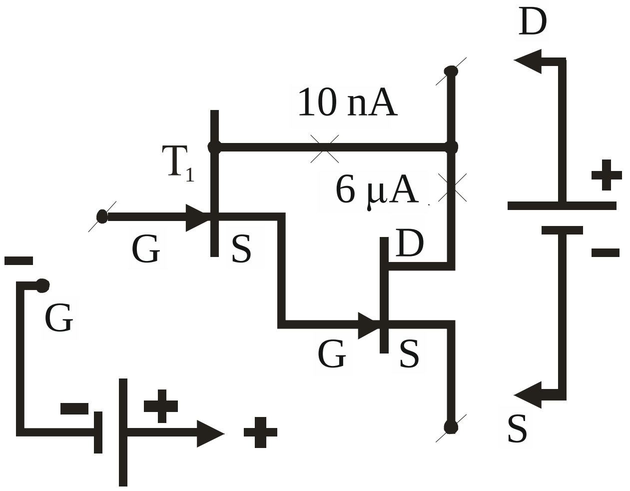
INTRODUCTION

Conventionally, field-effect transistors are operated in three classical ways of switching, i.e. the common source, common drain and common gate. But these three cases are not the only ones and in no way limited to them. As is well known, there is no such a semiconductor device, which would have broad functionality as a field transistor that could be operated as a photo-detector, temperature sensor,[1,2] pressure sensor,[3] magnetic field[4] and microwave generator, all are made possible by a variety of operating modes and switching diagrams. In physics, the field transistor is mainly regarded as a field-controlled amplifier, but the recent studies had shown that it can also operate as a current-controlled device, that is, in the mode of small direct bias at the gate. This in turn makes it possible to design on the basis of two field-effect transistors of a single compound transistor.[5]

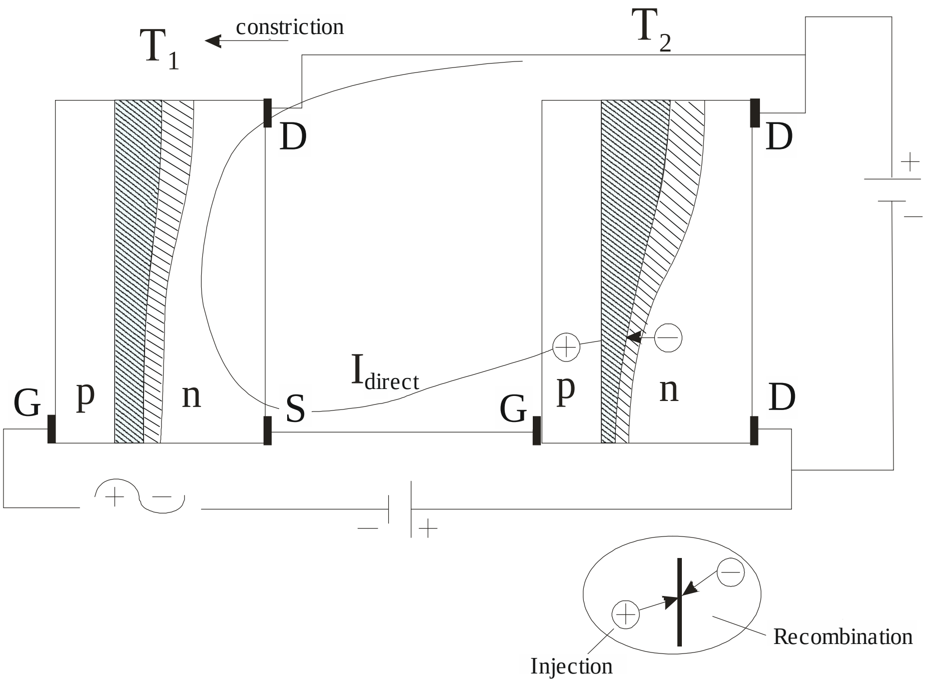
EXPERIMENT AND DISCUSSION

In it diagram, the drains are as one, and the source of the first transistor is connected to the gate of the second transistor. It is treated as single transistor. In general, the first transistor operates in the locking mode, whereas the second transistor operates in the direct displacement mode of the gate as shown on Fig.1a.

In the basic state when the voltage between the drain and the source was 4.5 V, the current through the channel of the transistor amounted to 6 μA, whereas the current flowing through the channel of the gate transistor and its directly displaced "gate-source" junction at gate voltage equal to $(U_C / 2) = 0.5V$ turned out to be 10nA. Here again, the voltage on a directly-displaced *p*-*n*-junction should be less than U_D to ensure the efficient operation. In this case, the gain factor due to the modulation of the channel resistance (due to the injection of minority hole carriers into the channel) is less than the voltage which is due to the modulation of the channel thickness by the space-charge region of the locked *p*-*n* junction. In a compound transistor, the thickness of the channel of the first transistor will change as a function of the gate voltage; this will lead to change in the voltage on the channel, which in turn will lead to a change in the current value through the directly biased transition of the second transistor.



a)[5]



b)

Fig. 1: Flow diagram of operating voltages on compound transistor assembled on field structures (a) and the channel modulation processes.

The mechanism for varying space-charge region of controlling junctions in a tandem transistor is as follows. In the basic state because of the voltage value U_{DS}, the second transistor at the drain side will be locked, and at the source side space-charge region will narrowing, since the locking voltage $U_{GS}/2$, will occur at "gate-source" junction (Fig.1b). Simultaneously, through the channel of the first transistor, holes are injected into the channel from the "drain – source" voltage. In this case, the voltage will predominantly fall in the lockable transition of the first transistor. The positive pulse of the input signal in the first field transistor will eventually cause narrowing of the space-charge region of the gate, while the conductivity of the channel will increase. Meanwhile, the volume charge area of the gate will also be narrowed on the second field transistor, which in turn will lead to the increase in conductivity. The injection of carriers through the channel of the first field transistor and the "gate – source" transition of the second field transistor will lead to an even greater increase in the conductivity of the channel, i.e., the current flow. As a result, the gain becomes practically independent of the drain voltage. For the second field-effect transistor drain current will be equal to.[5]

The mechanism of varying of space charge region is governed by formula:

$$I_D = I_{DMAX}\left(1 - \frac{U_D - U_G}{U_D + U_C}\right), \qquad (1)$$

and the gate current
$$I_G = I_{G0}\exp\frac{qU_G}{mkT} \qquad (2)$$

$$I_D = I_{DMAX}\left(1 - \frac{U_D - m\frac{q}{kT}\ln\frac{I_G}{I_{G0}}U_G}{U_D + U_C}\right), \qquad (3)$$

where $\beta = dI_c / dI_ç$ and the ratio of the current gain $\beta = \frac{2m(kT/q)I_{DMAX}}{(U_D + U_C)I_G}$. (4)

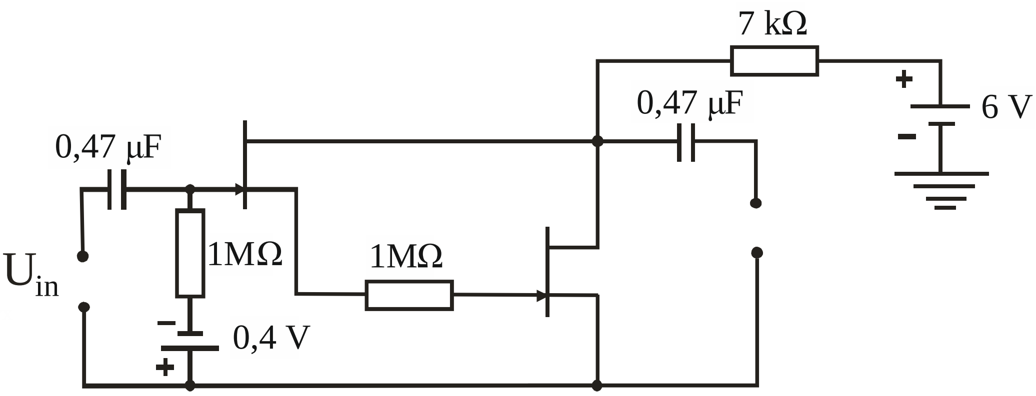


Fig. 2: Supplying operating voltages to compound transistor assembled on field structures.

Accordingly, the lower the gate current I_g and cut-off voltage, the diffusion potential, the greater the gain. Therefore, to increase the gain and receive weak signals, we propose to embed a resistor between the source and the gate as shown on Fig.2. When selecting the resistance between the source and the gate, taking the reverse current (20 nA) by an order of magnitude greater than the saturation current (2 nA).

$$R_{in}^{p-n} = \frac{kT}{q(I_{rev} - I_{sat})} \qquad (5)$$

We obtain resistance equal to 1.38 MΩ. Studies of the amplifying properties of a compound field-effect transistor at locking voltage of 0.4 V and with resistances at the gates of 1 MΩ made it possible to reach amplification of the sinusoidal signal with a gain ratio of 18, as shown in Table 1, which is three or even more times higher compared to cost-effective amplifiers built on three-stage structures.[5]

Table 1: Output signal value and gain value at different input levels.

f=400 Hz								
U_{in}, mV	1	2	4	5	8	10	15	20
U_{out}, mV	18	36	72	90	145	180	270	360
K_{gain}	18	18	18	18	18.1	18	18	18

CONCLUSION

In series-connected field-effect transistors, the modulated transition, as in two-barrier structures, controls the parameters of the second transition due to the redistribution of the voltage applied from the external power source.

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