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High-gain Cross-current Tetrode MOSFET/SIMOX and Its Application

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In a single MOSFET/SOI, a negative drain conductance property not due to the thermal effect[1] was found in the drain current(I_D) saturation region. In this paper, it is demonstrated that such a device is applicable to a high-gain analog amplifier.

The device was fabricated using the buried oxide by SIMOX technology[2]. Ground-plane and cross-sectional views of the device are shown in Fig. 1. This device will be referred to as HXT MOSFET/SIMOX, which is short for High-gain Cross-current Tetrode MOSFET/SIMOX. Notations "D", "G", "S" and "C" represent drain, gate, source, and the fourth control terminals, respectively. Structural parameters for measured devices are listed in Table 1. Typical drain current(I_D) vs. drain voltage(V_D) characteristics are shown in Fig. 2. Negative conductance appears at the I_D saturation region. The drain conductance property can be controlled by the incorporated fourth control terminal, which is quite different from conventional hybrid negative conductance devices[3].

An equivalent n-channel HXT circuit is shown in Fig. 3(a). HXT consists of n-channel MOSFET and p-channel JFET. The negative conductance property is caused since the gate bias of the parasitic JFET increases with the increasing drain bias of HXT. Because of this feature, an extremely small, positive drain conductance can be performed even in a very short-channel MOSFET/SIMOX by putting a bypass circuit between terminals "C" and "S" (Fig. 3(b)). Examples of I_D vs. V_D and drain conductance(G_D) vs. V_D characteristics are shown in Fig. 4. In the case shown in Fig. 4(b), drain conductance at 2V gate bias and 2.5V drain bias was less than 1uS. This was less than 1/1000 of the conventional MOSFET/SIMOX operation mode value, although transconductance(G_m) was 1/3 that of conventional MOSFET/SIMOX operation, that is, G_m-to-G_D ratio was larger than 300.

It was expected that the above feature of the HXT could be used in an analog amplifier. To explore this possibility, a single-stage differential amplifier was assembled using complimentary HXT. The employed circuit is shown in Fig. 5. The circuit diagram consists of the amplifier and feed-back loop. Fig. 6 is a photograph of a typical operation result. Output signal amplitude of 1.3 V was obtained from input signal amplitude of 4.2mV at 1 kHz: that is, a gain of 50 dB. This demonstrates that the HXT has great potential for analog-circuit applications.

References

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(2) K. Izumi, M. Doken and H. Ariyoshi,"CMOS devices fabricated on buried SiO2 layers formed by oxygen implantation into silicon",Electron. Lett.,vol.14,pp.593-594(1978).

(3) G. Kano and H. Iwasa,"A new-type negative resistance device of integrated complementary FET structure,"IEEE Trans. on Electron Devices, vol.ED-21,pp.448(1974).

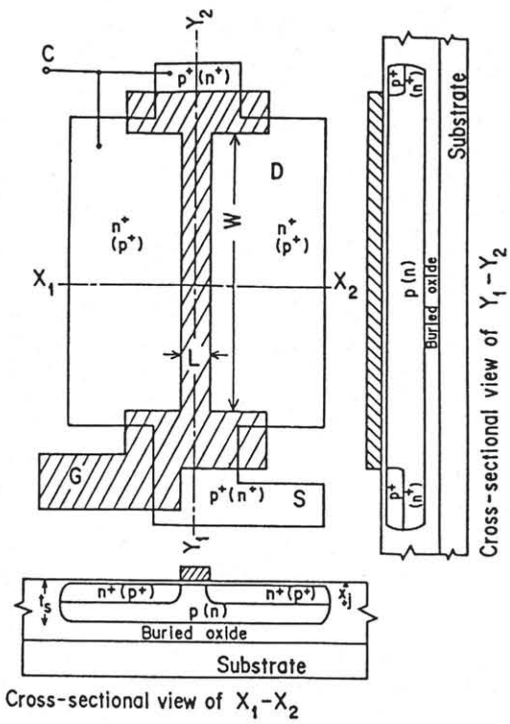


Fig. 1. Schematic diagram of HXT MOSFET/SIMOX

Table 1. Parameters of measured devices	
Parameter	Value
Gate length (L)	2.0 μm
Gate width (W)	100 μm
Gate oxide thickness (t_{ox})	20 nm
Active region thickness (t_s)	1.0 μm
Junction depth (X_j)	0.7 μm
Doping concentration	
nMOS (N_A)	$7.0 \times 10^{16} cm^{-3}$
pMOS (N_D)	$6.0 \times 10^{16} cm^{-3}$
Buried oxide thickness	0.16 μm

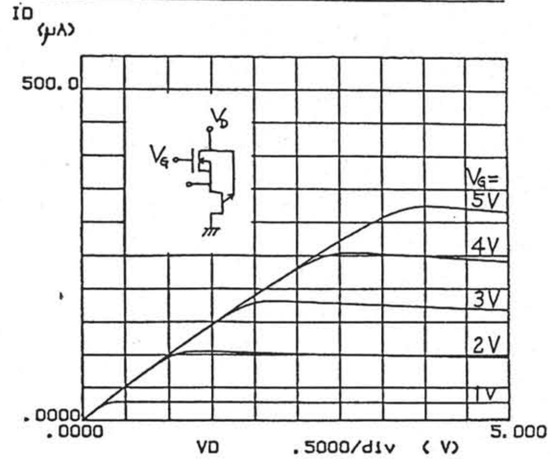


Fig. 2. I_D vs. V_D curves for HXT

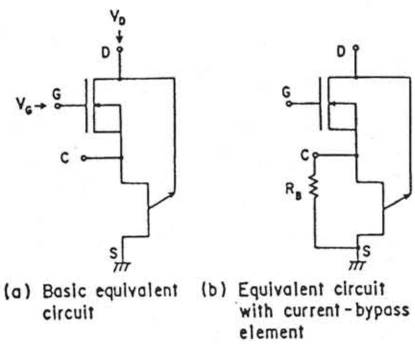
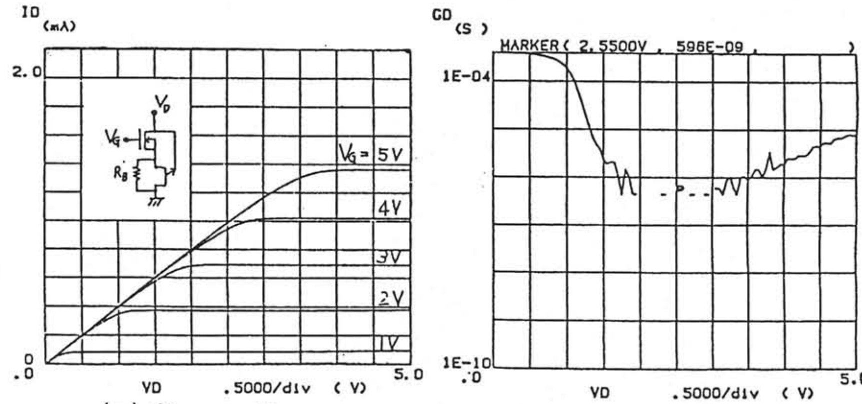


Fig. 3. Simplified equivalent circuit of HXT



(a) I_D vs. V_D (b) G_D vs. V_D

Fig. 4. Characteristics of HXT controlled by a bypass element (R_B=3.195kΩ)

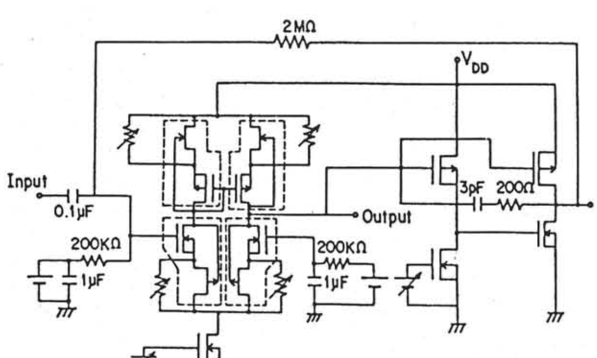


Fig. 5. Test circuit for amplifier operation

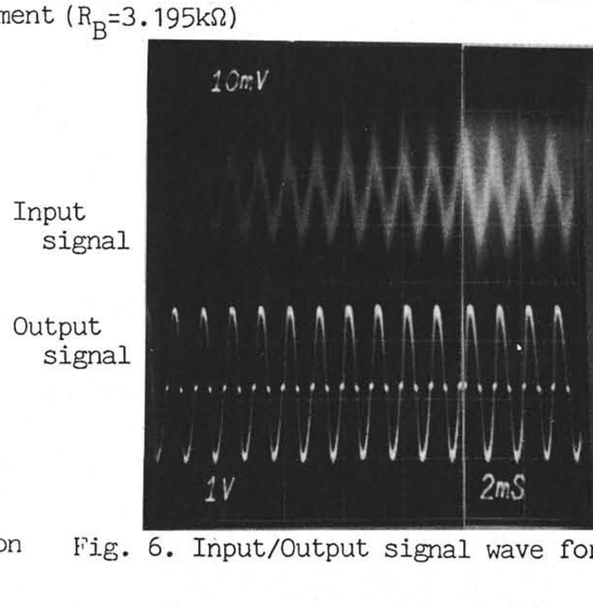


Fig. 6. Input/Output signal wave form