COOLED PREAMPLIFIER

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The paper concerns a preamplifier with direct coupling whose input field-effect transistor operates at 1.8-4.2 °K. The rise time of the transient response is ~ 30 nsec, and the voltage gain is ~ 15. The parameters of some high-frequency field-effect transistors with a *p-n* junction and a Schottky barrier at low temperatures are presented. The influence of a magnetic field with an induction of 0-3 T on the operation of field-effect transistors at temperatures of 1.8-4.2 °K is examined.

The amplification and transmission of signals generated at low temperatures is an important problem for low-temperature physics. The resistance of the signal source and the input resistance of the recording equipment must be matched allowing for the characteristic wave impedance of the cable to provide optimum speed rate and to reduce the level of interference induction and noise.

In studies of heat pulses [1] and the phonon-induced conductivity [2], it is necessary to assure the transmission of narrow saw tooth voltage pulses with durations of microseconds from a specimen at helium temperatures. The pulse-repetition frequency is of the order of tens of Hertz, the amplitude is several micro Volts, and the pulse rise time is ~ 40 nsec. To solve this problem, a preamplifier was designed whose input field-effect transistor (FET) was placed in the immediate vicinity of the specimen and operated, unlike well-known analogs [3], at temperatures of 1.8-4.2°K and magnetic fields of 0-3T.

The electrical circuit of the preamplifier is given in Fig. 1. The input FET T_1 is connected to a common-source circuit, and a compound stage is built around the transistors T_2 and T_3 [4] to form a parallel cascode circuit. This connection means only one signal cable need be used and eliminates redundant components in the low-temperature vessel. Transistor T_2 is connected to the common-base circuit and wrapped by two feedback loops.

A local current-active feedback on the through Transistor T_3 reduces and stabilizes the input resistance of transistor T_2 over a broad frequency band. A coaxial cable is matched at the receiving end by the resistor R_1. The voltage across the FET channel is set by the variable resistor R_4 at the beginning of the gently slopping area of its drain characteristic.

The de-feedback loop is closed through an emitter follower T_4 and inverting integrator OA_1. The time constant of the integrator is 0.1 sec. This determines the lower boundary of the amplified frequencies. The voltage gain at midband frequencies is defined as $Y_{fs}\, R_2\, R_3\, (R_2 + R_3) = Y_{fs} \cdot$ 2kΩ, where Y_{fs} is the transconductance of the input FET T_1. To stabilize Y_{fs} over a wide temperature range, the local current feedback through the source resistor may be used [4].

The rise time of the transient response of the preamplifier, which is measured at the levels of 10 and 90%, is 30-35nsec, provided that signals come from sources with low internal resistances. It is determined by the collector network of transistor T_2 When the real part of the impedance R_s of the signal source exceeds 10kΩ, allowance should be made for the input capacitance of the FET, which is 3.5pF for 2P312 FETs and 0.5pF for 3P324 and 3P325 FETs.

The input devices tested were 2P312 silicon FETs with an *n*-type channel and *p-n* junction and 3P324 and 3P325 gallium arsenide FETs with *n*-type channel and Schottky barier. Measurements of the drain and gate characteristics showed that the FET transconductance Y_{fs} increases by ~ 1.5 as the temperature drops to ~ 100°K, and then remains approximately constant to 2°K. Over the range of 1.8-4.2°K the value of Y_{fs} is ~ 5mS for 2P312 FETs (the voltage between the drain and the source was V_{ds}=

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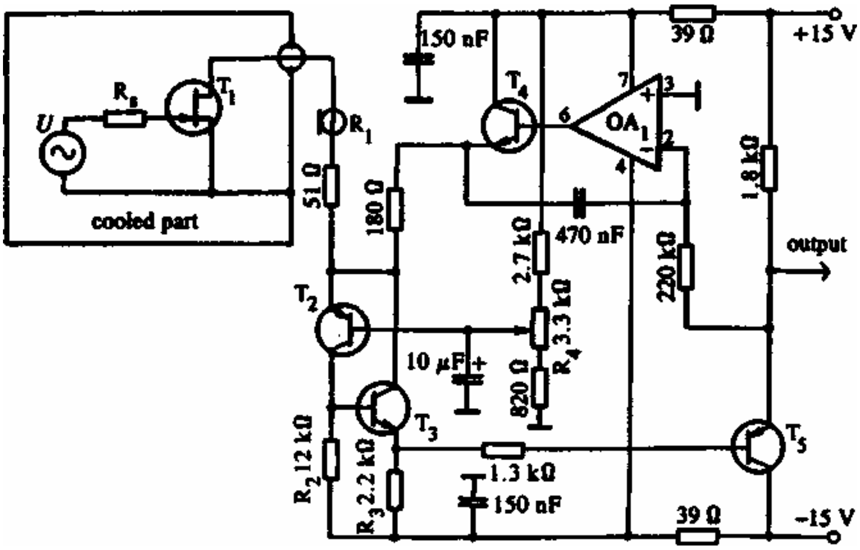

Fig. 1. Electric circuit of the preamplifier: OA$_1$) 140UD7; T$_1$) 3P324, 3P325; T$_2$. and T$_5$) 2T326B; T$_3$) 2T321A; T$_4$) 2T928A. The OA$_1$ balancing network is not shown.

5 V and the voltage between the gate and the source was V_{gs} = 0), ~ 5 mS for 3P324 FETs (V_{ds} = 3 V and V_{gs} = 0), and ~ 7 mS for 3P325 FETs (V_{ds} = 3 V and V_{gs} = 0). As the temperature decreases below 25 °K, the transient response of the 2P312 transistor becomes differential. Under the action of rectangular voltage pulses V_{gs}, the amplitude of the drain-current spike was ~ 30% of the steady-state value, decaying with a time constant of microseconds. At those temperatures the 2P312 FET has significant levels of current noise, which was mentioned in [5]. At temperatures of 1.8-4.2 °K and magnetic fields of 0-2 T the 2P312 FET transconductance decreases by ~ 40% with the following abrupt reduction of Y_{fs} by the factor of four at magnetic fields of 2-3 T.

3P324 and 3P325 gallium arsenide FETs with Schottky barriers have none of these drawbacks. The amplitude of the drain-current spike under the action of the V_{gs} voltage step does not exceed 3%. The mean-square voltage noise at frequencies of 10 kHz-10 MHz, measured by the method in [6] and reduced to the input, does not exceed 10 μV. At magnetic fields of 0-3 T and temperatures of 1.8-4.2 °K, no dependence of Y_{fs} on the magnetic field could be discovered to within the accuracy of the measuring apparatus (5%).

The cooled preamplifier was utilized as one of many engineering tools to study heat pulses and phonon-induced conductivity. Signals from phonon-induced conductivity and time-of-flight phonon spectra in a silicon crystal measured using the preamplifier are given in [7]. The preamplifier was placed inside the block of a Ya40-1100 differential amplifier of an S1-74 oscillograph and powered from the oscillograph basic supply. The signal from the output of the Ya40-1100 amplifier is passed to the Ya4S-88 programmable stroboscopic converter operating under computer control.

The fall in the FET gate's leakage current at lower temperatures [3, 5] allow them to be used to measure small direct currents. For 3P325 devices the dc of gate leakage does not exceed 0.1 pA at temperatures 1.8-4.2 °K.

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