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The inherent low noise of the field-effect transistor (FET) made it an attractive candidate for the input stage of high resolution preamplifiers. Recently, a number of preamplifier circuits using an FET in the input stage have been published.[1, 2, 3] This letter describes briefly a low-noise FET preamplifier (pulse generator resolution 0.7 keV FWHM) with which 1.1 keV resolution was achieved in measurement of γ-ray spectra of ^{57}Co. The approach followed in the design of the described preamplifier was based on the optimization of the signal-to-noise ratio. The following steps were taken to achieve this purpose:

a. The input stage was inserted into the chamber containing the detector.
b. The input stage was simplified by insulating the detector from ground.
c. The FET was cooled to improve its signal-to-noise performance.
d. High frequency filters were used inside the charge-sensitive amplifier,
e. Careful layout was made for the input stage and the following sections.
f. A special low-capacitance and low-leakage lithium-drifted germanium detector was used.

The block diagram of the preamplifier is given in Fig. 1. The detector used is a LRL-Livermore-type lithium-drifted germanium diode with dimensions $3\times1\times0.3$ cm and capacitance of 1.9 pF.[4] The bias voltages used for this type of detector are in the range of 700 to 1500 V, and the leakage currents range from 0.5 to 3 nA. This low leakage is obtained keeping the detector cooled to liquid nitrogen temperature in vacuum of 2×10^{-7} mm Hg.

The charge signal delivered by the detector is applied to a charge-sensitive amplifier composed of common-source FET stage, an integrator and amplifier 1. The capacitive negative feedback of this high-gain configuration ensures its charge sensitivity and the stability of output signal with changes of the detector's capacitance.

As mentioned before, the FET stage was mounted inside the chamber containing the detector. The following advantages were gained by this mounting:

(a) Input stray capacitance is minimized by bringing the FET as close as possible to the detector and eliminating the capacitance of the feed-through terminals.

(b) The cooling of the field-effect transistor is simplified.

(c) The inherent shielding of the input stage by the metal chamber containing the detector is very effective in eliminating the low-frequency noise which might otherwise saturate the preamplifier.

The complete circuit diagram of that part of the preamplifier included inside the detector chamber (shown inside the dashed line in Fig. 1) is given in Fig. 2. The n-channel FET used (2N 3823) has a small input capacitance (6 pF max) and a high gm (3500 to 6500 μmhos) at zero bias and at room temperature. The optimum signal-to-noise performance of the FET was found to be at the temperature of approximately -130°C. Also, for optimum performance it is necessary to select the FET's. Another n-channel FET which gave slightly poorer performance was 2N3684.

[illegible]

Further improvement of the signal-to-noise ratio of the charge-sensitive amplifier was achieved by filtering the output of the FET stage. This is done by the integrator (0.1 μsec time constant) and by choosing low-f_T transistors for amplifier 1. The output signal of the charge-sensitive section is amplified by feedback amplifier 2 (gain of 10) in order to diminish the influence of low-frequency pickup by the cables between the preamplifier and the main amplifier.

The preamplifier performance was checked with pulse generator and radioactive sources. The conventional pulse generator test was carried out with a mercury-relay type RIDL pulse generator Model 47-3. An amount of charge simulating the γ-ray energies of ^{57}Co was inserted in the input of the FET through 0.5-pF capacitor, which was disconnected after the test. Noise line width of 0.7 keV FWHM was obtained with zero external capacitance when the FET was cooled to its optimum temperature.

The preamplifier assembly was checked for actual resolution with x rays of Pt and γ rays of ^{57}Co and ^{60}Co. The bias voltage for the detector was 1200 V,and the pulse-shaping time constants of the main amplifier were 0.5 μsec integration and 5 μsec differentiation. The pulse-height analyzer spectrum of Pt x rays and ^{57}Co γ rays is given in Fig. 3. The lines shown are K_α x rays (65.12 keV, 66.83 keV) and K_β x rays (75.75 keV, 77.87 keV) of platinum, and the γ rays (121.94 keV, 136.31 keV) of ^{57}Co. An expanded spectrum of the Pt x rays is shown in Fig. 4. From this spectrum the separation of the K_α group to K_{α_1} and K_{α_2}, which are only 1.71 keV apart, can be seen. Also the K_β group is resolved into K_{β_1} and K_{β_2} (2.12 keV apart). The resolution measured from Figs. 3 and 4 is 1.1 keV FWHM. This resolution was not critical with bias voltage in the range 1000 to 1300 V and with the pulse-shaping time constants. The resolution obtained for the γ rays (1.17 MeV and 1.33 MeV) of ^{60}Co was 5.7 keV. This degradation in resolution is due to the low efficiency of the detector (small size) for the high-energy γ rays.

It is felt that the reported results can be improved beyond 1 keV by decreasing further the input capacitance of the preamplifier by using integrated circuit techniques with the FET and the detector deposited on the same wafer. Also, from comparing the pulse generator and analyzer resolutions, it can be seen that further decrease in the detector noise and capacitance will be welcomed.

Detailed description of the preamplifier and performance data will be published in the near future.

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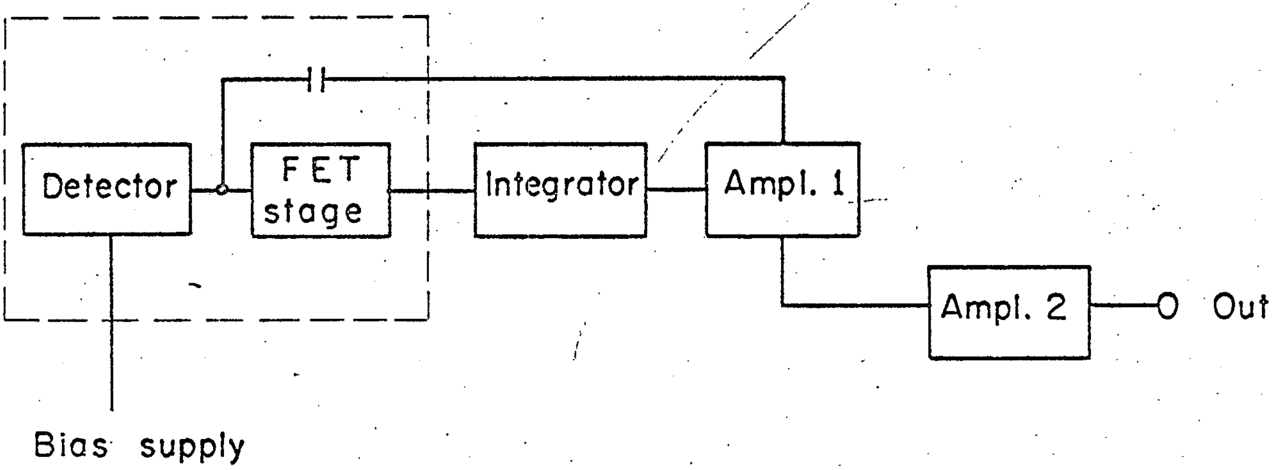

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Fig. 1. Block diagram of the preamplifier.

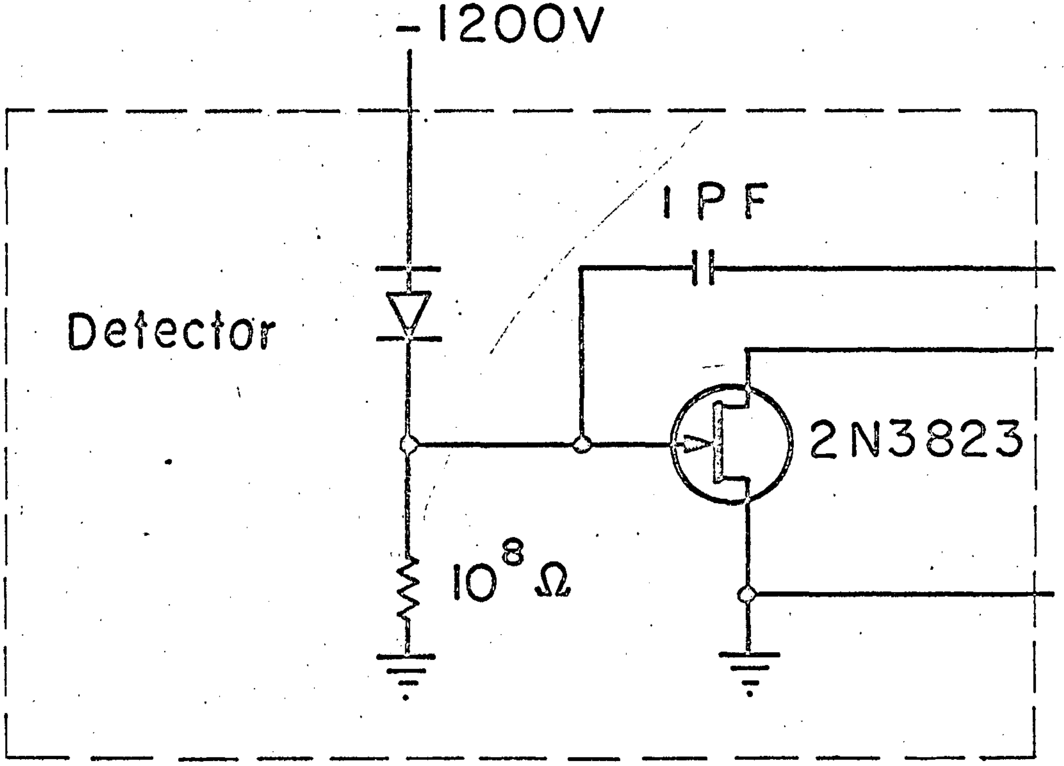

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Fig. 2. The input stage of the preamplifier.

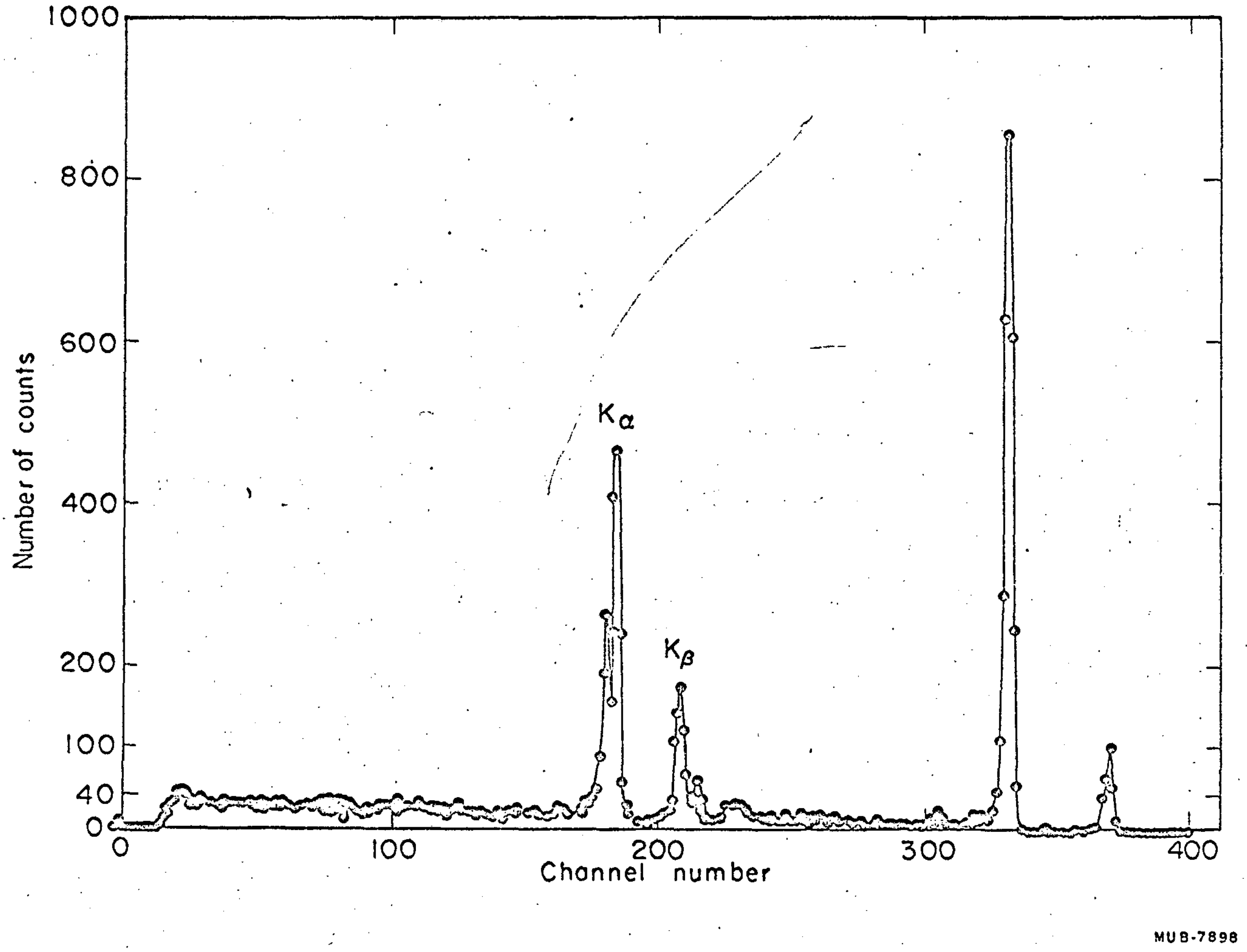

Fig. 3. Platinum x rays and ^{57}Co γ rays.

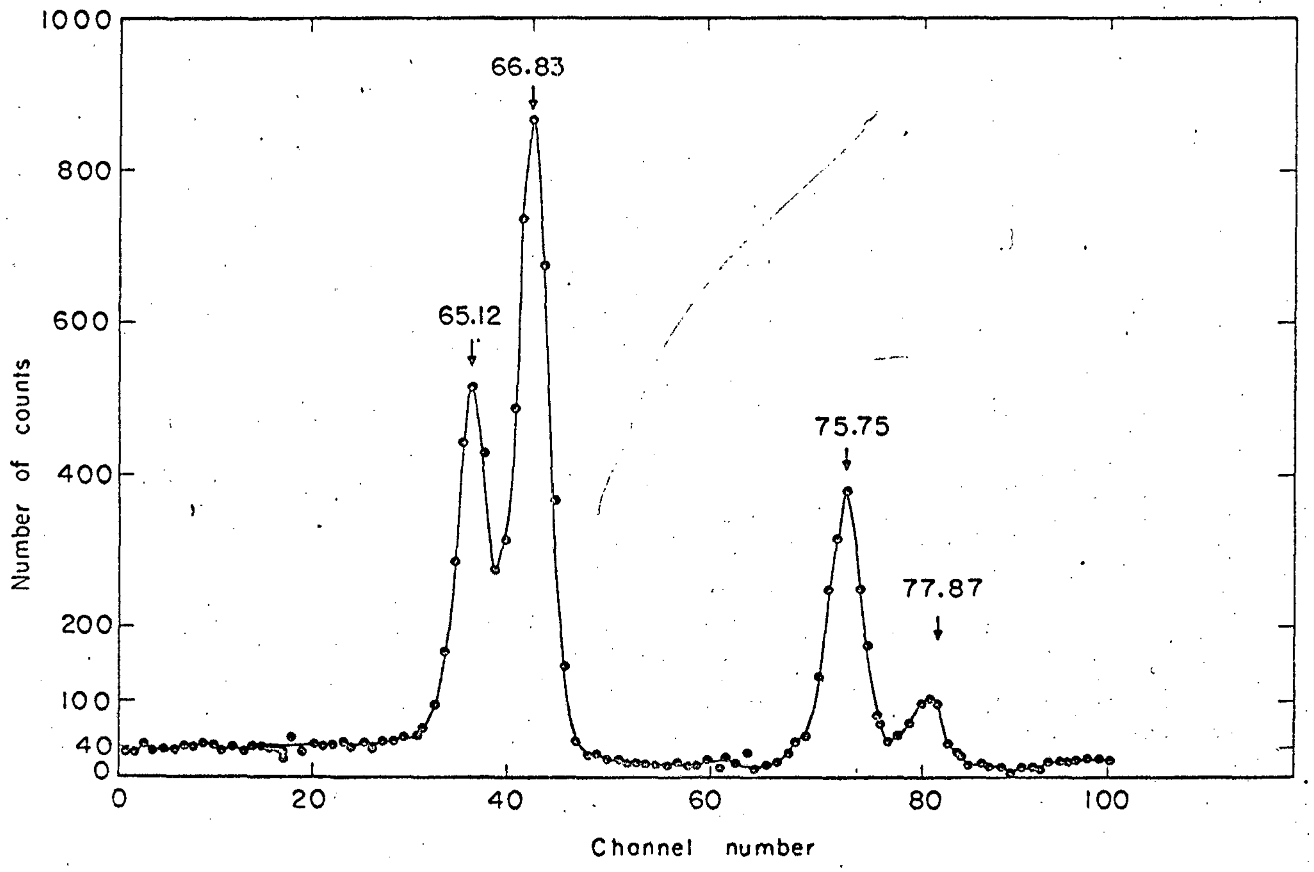

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Fig. 4. K_α and K_β groups of platinum x rays.