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LOW POWER, LOW NOISE JFETS FOR ROOM TEMPERATURE X-RAY DETECTORS

L. Sturm, L. Nebrich, K. Neumeier, I. Eisele, C. Kutter

Motivation

High resolution high count rate applications in x-ray fluorescence spectroscopy require input transistors with very low input capacitance (<1pF), very high input impedance (>10^{13} Ohm) and 1/f low noise. JFETs can serve both requirements and are established. Higher count rates require shorter filter-constants τ. In order to keep noise levels low, transition frequency f_T of the input transistor has to rise.

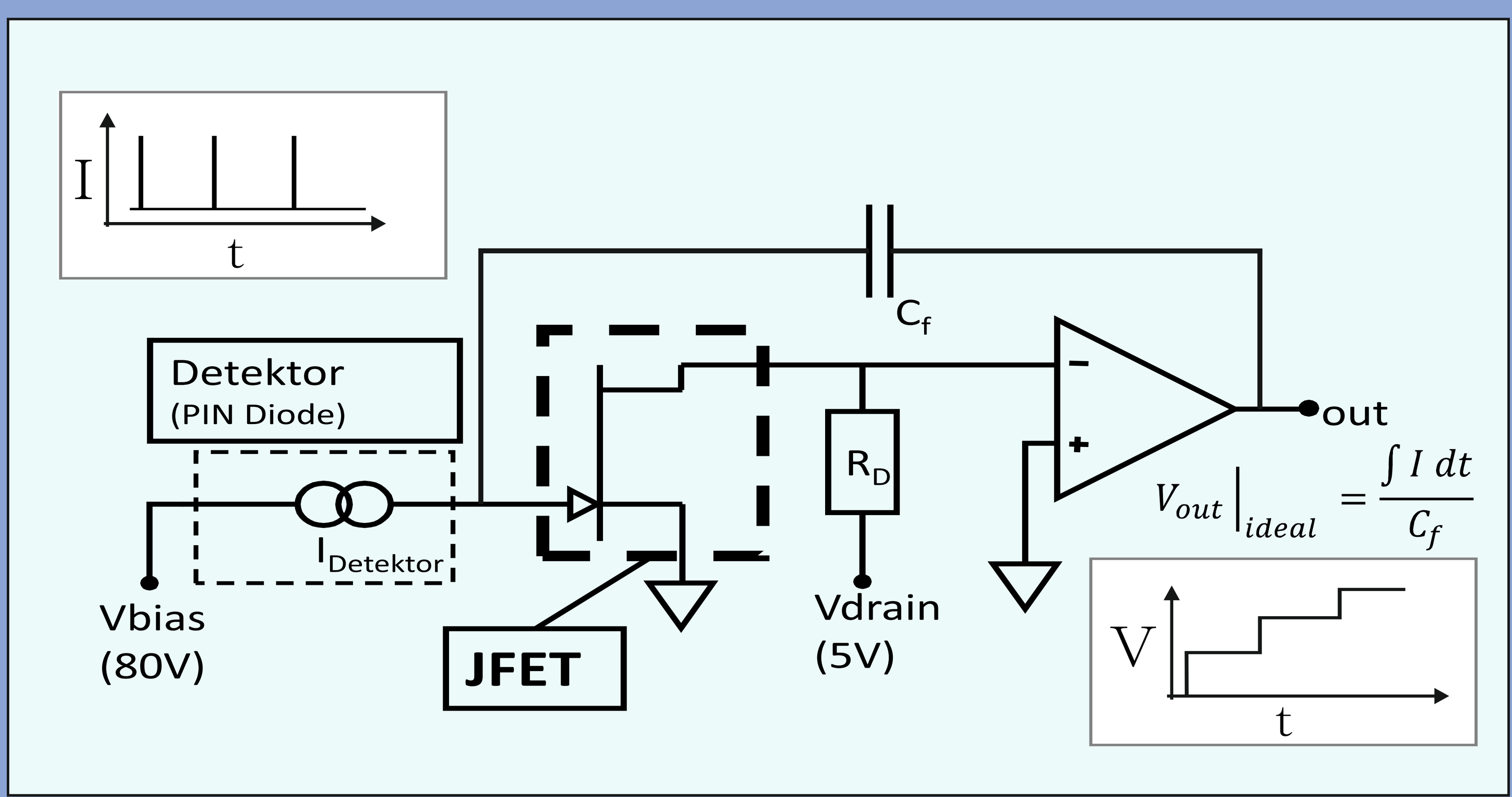


Figure 1: Schematic of a charge amplifier with JFET as input transistor.

Noise in Charge Amplifiers

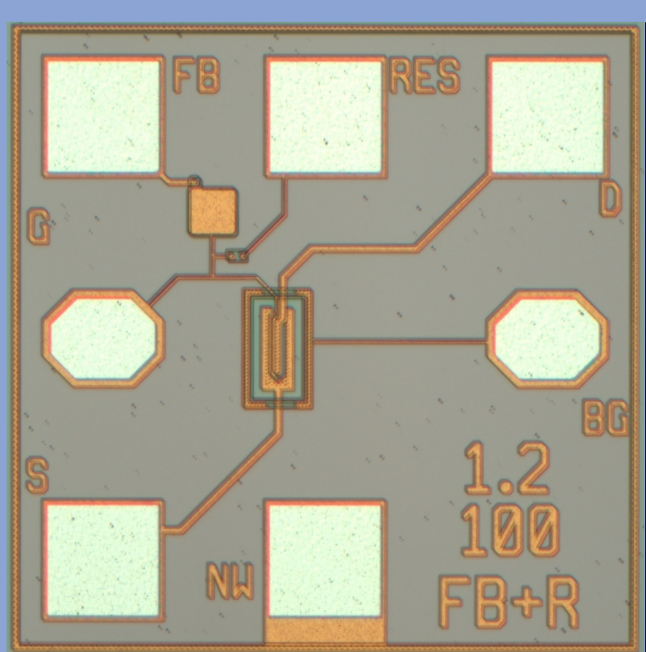
Noise is expressed as equivalent noise charge at the input. There are three main components which depend on the input transistor: 1/f type serial noise (1/f), white series noise (ws) and white parallel noise (wp) [1].

$$ENC_{\frac{1}{f}}^2 \propto \frac{f_c}{f_T} \qquad ENC_{ws}^2 \propto \frac{1}{f_T}\cdot\frac{1}{\tau} \qquad ENC_{wp}^2 \propto \tau\, I_{LT}$$

[1]

Fabrication Results

To minimize noise contributions, the fabrication process was optimized to achieve higher f_T=gm/(C_{gs}*2π) while keeping the flicker corner frequency f_c low and I_{LT} below 1pA at operation point.



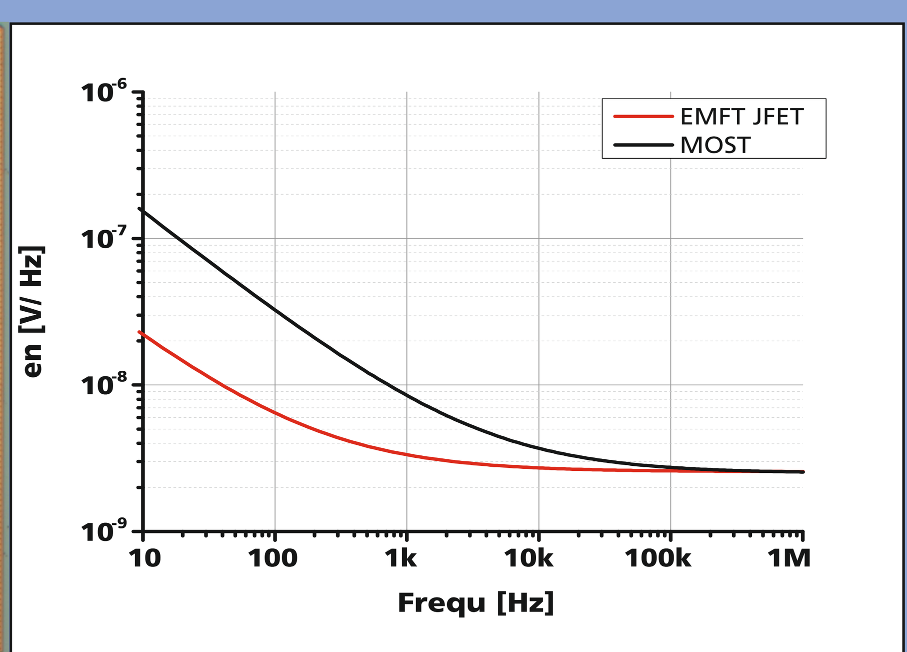


Figure 2: Chip of 100 1.2 with integrated feedback capacitance and reset-diode.
Figure 3: Comparison of a measured noise spectrum of a 400 1.2 and a noise spectrum of a typical P-MOSFET in 1µm technology.

JFETs with gate length down to 1.2µm and gate width ranging from 100 to 800µm have been fabricated.
For low power consumption the JFETs were processed to have a pinch-off voltage of -1V to achieve gm/Ids_0 ≈2 and a saturation voltage of 1V. The power consumption of the 100 / 1.2 transistor is only 4.5mW at bias point Vgs=0V Vds=3V.

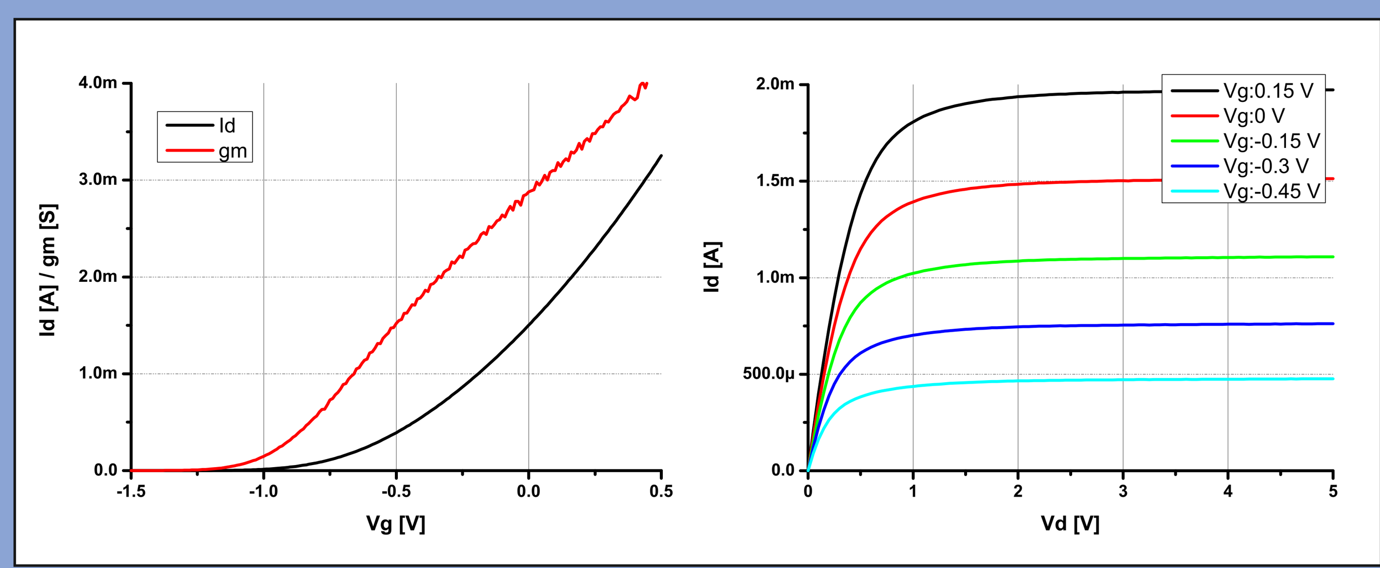
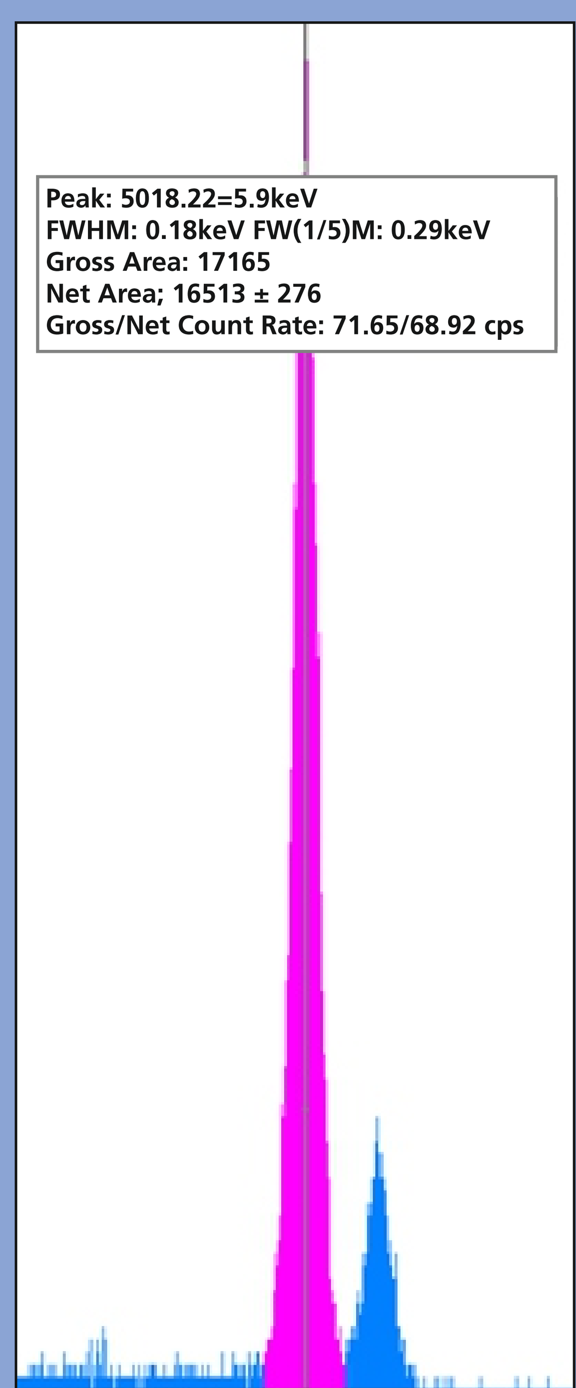


Figure 4: Input characteristic of 100 1.2 transistor.
Figure 5: Output characteristic of 100 1.2 transistor.

Device: W / L [µm]	f_T [GHz]	f_C [Hz]	I_{LT} [pA]	gm [mS]	C_{gs} [pF]	Ids_0 [mA]	gm/Ids_0 [1/V]
100 / 1.2	2.2	400	0.2	2.8	0.24	1.5	1.9
400 / 1.2	2.4	200	0.7	10	0.85	5	2
800 / 1.2	2.4	100	1	20	1.75	10	2
2N4416[3]	0.43	<10k	<1	6	2.2	10	0.6
MX10[2]	1.3	<1k	-	6.5	0.8	-	-

Table 1: Comparison of figures of merit to other devices. Measurement conditions for the Fraunhofer EMFT JFETs are Vds=3V Vgs=0V, temperature 23°C.



Application Results

An x-ray spectrum of the Fe-55 decay was measured with 100 1.2 JFET with a 1pF detector capacitance PIN-diode at 3µs shaping-time at room temperature without additional cooling. Measured full-width-half-maximum of Mn K-alpha is 180eV. The measurement was done with a charge-amplifier of FirstSensor AG and an ORTEC-spectrometer.

Acknowledgement

We wish to thank Dr. Thomas Göbel from FirstSensorAG for providing the measurement data of the x-ray fluorescence measurement.

Figure 6: Spectrum of Mn K-alpha, K-beta measured with 100 1.2 JFET.

[1] Bertuccio, G., Pullia, A., and Geronimo, G. de, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 380(1-2):301–307, 1996.
[2] Mark W. Lund, Nuclear Instruments and methods in Physics Research A 380:318–322, 1996.
[3] Vishay, "Datasheet 2N4416,"