OUTPUT AND TRANSFER CHARACTERISTICS AND NOISE ANALYSIS OF CMOS TECHNOLOGY

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ABSTRACT

Pyroelectric infrared (PIR) detectors convert the changes of incoming infrared light to electric signal. Pyroelectric materials are characterized by the spontaneous electric polarization, which is altered by temperature changes infrared light illuminates the elements. Since the measured sensor series uses this effect they can be used at ambient temperature even in the presence of thermal noise. By choosing appropriate IR receiving electrodes, they serve a wide range of applications. Sometimes PIR generate a false alarm. They include thermal resistor and FET device which can be a source of random signals. This paper deals with the measurement of output and transfer characteristics and low frequency voltage noise spectral density. By the help these characteristics we can evaluate detectors and reduce false alarms.

1. INTRODUCTION

The sensitivity of electrical systems is limited by noise. Very important source of noise in electronic systems are electronic devices that form the heart of the signal processing and transmission components in these systems. These are irreducible sources of noise, and it is very important to realize their properties and characteristics.

In the last decade 1/*f* noise in channel layers has been studied extensively. It became evident that occurrence of 1/*f* noise can serve as a measure of the technology standard. We concentrated our efforts on 1/*f* noise to find the correlation between the occurrence of 1/*f* noise and generally the manufacturing technology.

The main problem consists in the identification of the source of this kind of noise. Current theories of 1/*f* noise assume that there are two sources of 1/*f* noise, namely, i) fundamental quantum 1/*f* noise and ii) excess 1/*f* noise. According to Hooge [1], 1/*f* noise is due to carrier mobility fluctuations.

It is frequently observed that excess 1/*f* noise is related to the microscopic sample structure and the manufacture technology. This kind of noise is particularly sensitive to surface and interface defects [2]. There are manufacturing techniques which give small dispersion of the mean characteristic values, such as resistance or current. On the other hand these devices can exhibit large dispersion of the noise characteristics. So, for example, metal thin film resistors have lower 1/*f* noise than granular film resistors made from cermet thick films or carbon resistors.

2. PYROELECTRIC IR DETECTORS

Pyroelectric detectors are made of a crystalline material which generates a surface electric charge when exposed to heat in the form of infrared radiation. When the amount of radiation striking the crystal changes, the amount of charge also changes and can then be measured with a sensitive FET device built into the sensor is shown in Fig. 1.

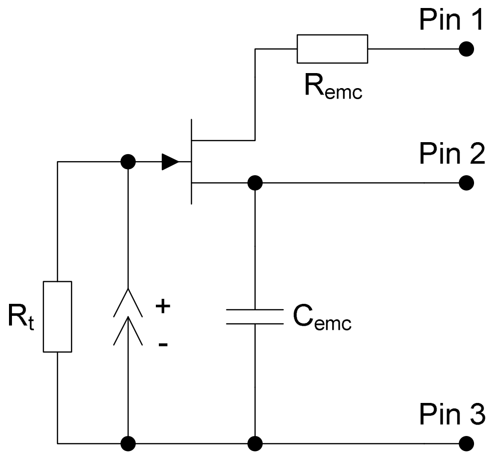

Fig. 1: Device schematic of PIR detector with source follower.

These detectors contains a single lithium tantalate sensing element and a FET source follower sealed into a standard TO-5 transistor package with an optional filter. A patented element mounting technique is used to improve thermal time constant and reduce effects of microphony. A source resistor is needed to set the drain current and consequently the operating parameters of the FET.

3. NOISE MEASUREMENT TECHNIQUE

The block diagram of the basic apparatus is shown in Fig. 2. Measuring set-up consists of noise voltage source, low impedance low noise preamplifier, optional passive LP or HP filter and also with computer which serves for processing of measured data and in our case also for controlling of the preamplifier.

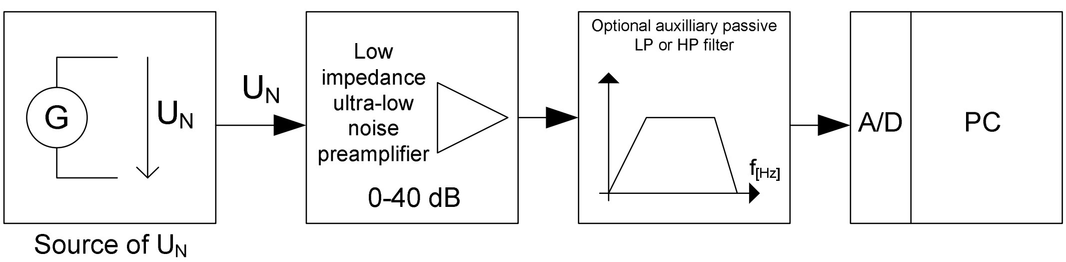

Fig. 2: Block diagram of the experimental set-up

Noise signal, which is a random physical process, is fetched to low noise amplifier where the extremely low signal is amplified to the level, which is acceptable for further processing with A/D card in a computer. Due to low level of noise signal mentioned above, we require unique properties of the amplifier, the emphasis is laid especially on amplification (typically 100 dB and more) and also on intrinsic noise of the amplifier (exemplary 10^{-18} V^2/Hz), which must be much lower than the level of measured noise. The amplifier is also equipped with selective filters (slope at least 40 dB/decade) to obtain the amplified signal in a selected narrow band and communication interface for controlling its functions by computer.

It is necessary to keep certain conditions during the measurement to obtain correct interpretation of measured data. The main effects which may affect measured data are:

- modification of temperature or intensity of magnetic or electric field during measurement,
- parasitic signal 50 Hz,
- decrease of power supply voltage.

4. EXPERIMENTAL RESULTS

Results of the measurements include basic output characteristics and voltage noise spectral density of PIR detector and n-MOSFET. The PIR detector was describe in chapter 2. It consists of a single lithium tantale sensing element and FET source follower. The n-MOSFET is a transistor from industry – BS108.

4.1. MEASUREMENTS OF OUTPUT CHARACTERISTICS

All output and transfer characteristics were measured at the temperature T = 300 K. In the next work it will measure for higher temperature to about T = 350 K. Basic output characteristics measured for the PIR detector for different values of gate voltage are shown in Fig. 3. Transfer characteristic of PIR detector measured for drain voltage U_d = 1.4 V is shown in Fig. 4. Output characteristics can be fitted by equation:

$$I_d = I_{d0}(1\text{-exp}(-\beta U_d) \qquad (1)$$

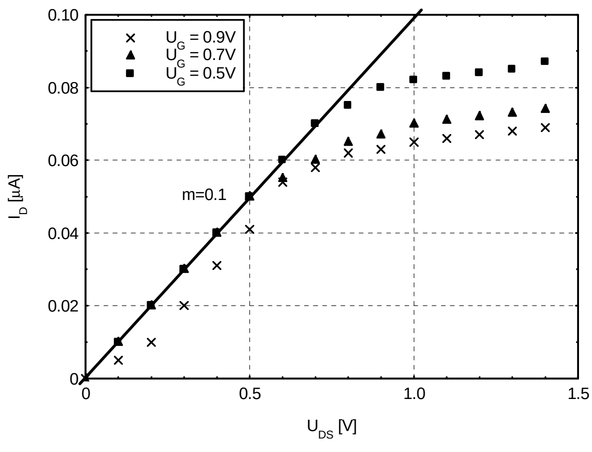

Fig. 3: Basic output characteristics of the PIR detector.

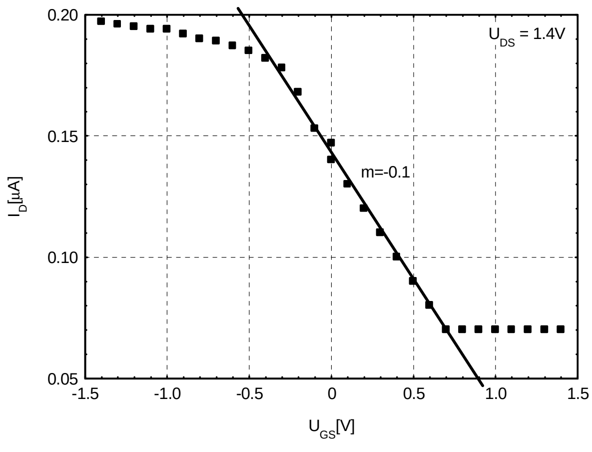

Fig. 4: The basic transfer characteristic of the PIR detector.

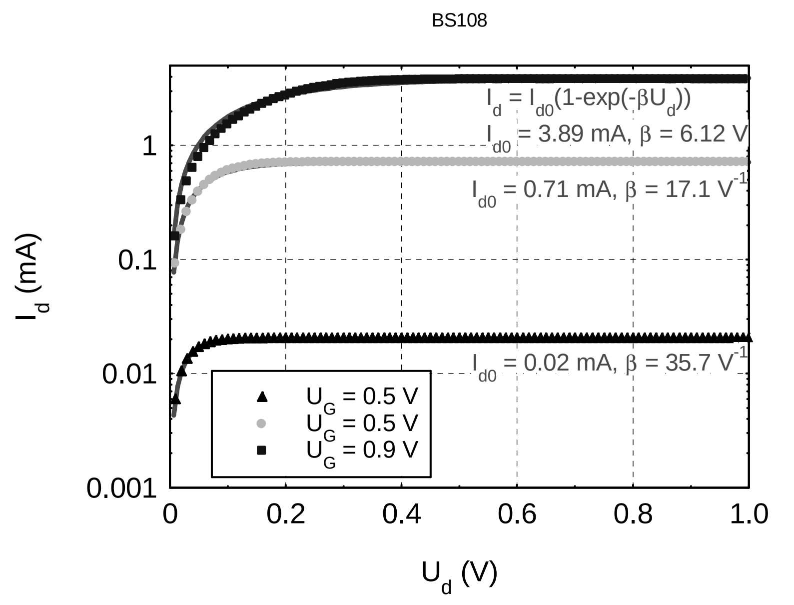

Fig. 5: Basic output characteristics of n-MOSFET BS108 at the temperature 300 K for U_G = 0.5, 0.7 and 0.9 V.

4.2. MEASUREMENTS OF NOISE SPECTRAL DENSITY

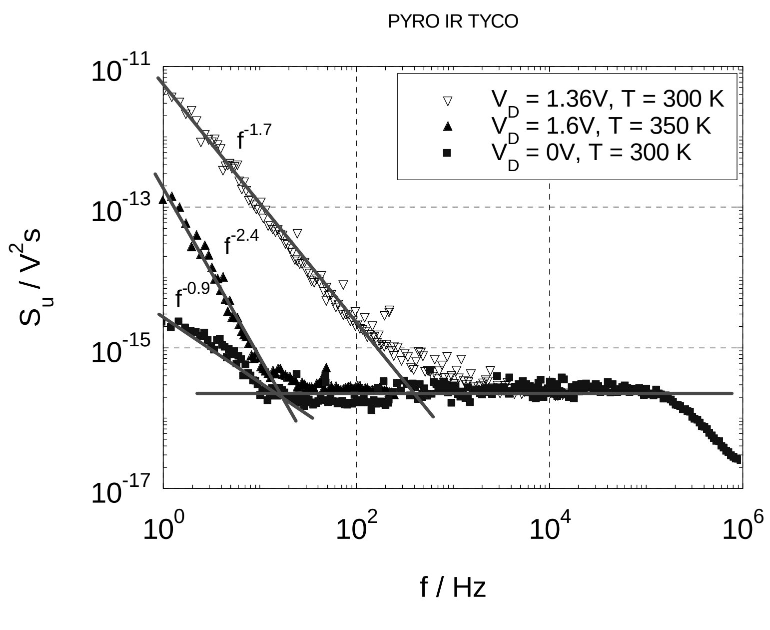

Fig. 6: The voltage noise spectral density of a PIR detector.

All technologies give rise to approximately the same behavior from the point of view of the 1/*f* noise. The noise spectral density for detectors can be described as a superposition of $1/f^a$ noise and thermal noise. The voltage fluctuation spectral density S_U versus frequency plot for PIR detector is shown in Fig. 6. The plot consists of two components, namely, *a* - thermal noise, whose spectral density $S_{UT} = 4kTR$, and *b* - 1/*f* type noise.

The general empirical relation for voltage noise spectral density is given by:

$$S_U(f) = C\frac{U^\beta}{f^\gamma}, \quad (1)$$

where β = 2, and γ= 1, constant C can be expressed using Hooge parameter α_H and the total number of particles, taking part in the conduction process.

5. CONLUSION

Almost all modern PIR detectors consist from the basic semiconductor FET. Measuring of output characteristics and the voltage noise spectral density FET is very beneficial to describe PIR detectors. For next work it will be finalization of experimental set-up for PIR detectors ultra-low frequency noise measurements and noise sources origin determination and their frequency spectrum localization.

ACKNOWLEDGEMENT

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