DIGITAL ANALYSIS OF WIDEBAND NOISE IN MOSFET’S

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ABSTRACT

The noise spectroscopy is one of the promising methods used for determination of quality and reliability of semiconductor materials. This paper deals with a new approach of power spectral density (PSD) estimation of wideband random process, based on design of octave digital bank filter. For calculation of filter bank, fast fourier transform (FFT) algorithm is used. In comparison with present method for PSD computation, the main advantages are better resolution for very low frequencies and minimization of background noise for measuring setup.

1. INTRODUCTION

Generally, present non-destructive methods for quality and reliability testing of micro and nano electronic devices are based on time evolution of selected parameters from transport and noise characteristics during the long-time intervals at increased temperature and load. Deviations from the expected noise can be used as a diagnostic tool for the device quality. Some fundamental noise sources are well understood, but there is a pretty often measurable noise phenomenon with a spectrum proportional to 1/f. This leads to the name 1/f noise. The physical origin of this noise is still unknown, but present theories of 1/f noise assume that there are two sources of 1/f noise, fundamental quantum 1/f noise and excess $1/f^{a}$ noise. We suggest that flicker noise is caused by electromagnetic interactions among the fluctuators or that chemical defects and mobile impurities make source of this kind of noise. For experimental studies of random processes, experimental study of measurable quantities, as the noise voltage or current and theirs spectral density dependence are used. Principal scheme of measuring set-up is shown in fig. 1.

For alternating signal, sample and resistor R_L are connected in parallel, thus the noise voltage is measured directly on resistor R_L. The random noise signal is than measured by the selective DC nanovoltmetr or amplified up to sample level with universal low noise amplifier and digitized with the PC card (e.g. Advantech 1716L with 16bit A/D converter) or digital oscilloscope(e.g. Agilent 54600A). Discrete signal is stored to a hard drive on PC, converted data signals are served for power spectral density estimation generally using non-parametric methods such as correlogram or periodogram. These methods use as a computational procedure for Discrete Fourier Transformation Fast Fourier Transform algorithm. Main disadvantages are that quantizing noise with A/D conversion increases for each measured frequency band and also demands for conditions and quality of selective analog filters are very high. Implementation of analog filtration to digital one and further computer processing of measured signals will reduce the costs, simplify the measurement set-up and reduce the background noise.

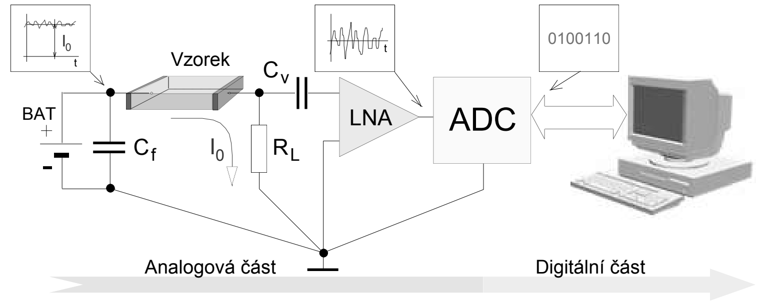

Fig. 1: Noise measuring set-up.

2. DIGITAL BANK OF FILTERS

The study of stochastic phenomenon and tracing redundant low-frequency noise in semiconductor materials require long-term measurements in time domain and evaluate suitable power spectral densities (PSD). We have used the means of time-frequency analysis for processing of very long-sequence samples of random signal. A novel scheme of digital octave-filter bank based on the discrete-time wavelet sub-band decomposition [1] was designed. Analysed signal $x(n)$ is divided to M bands with ascending exponential distribution that spread whole frequency band linearly till the half of sample frequency $f_s/2$. For each band is signal equal to ${}_m x(n)$, where $m \in$ and power spectral density $S_{xx}(\omega_m)$ is computed from one of the parametric method. Block scheme of power spectral density estimation using digital bank filter is shown in fig.2.

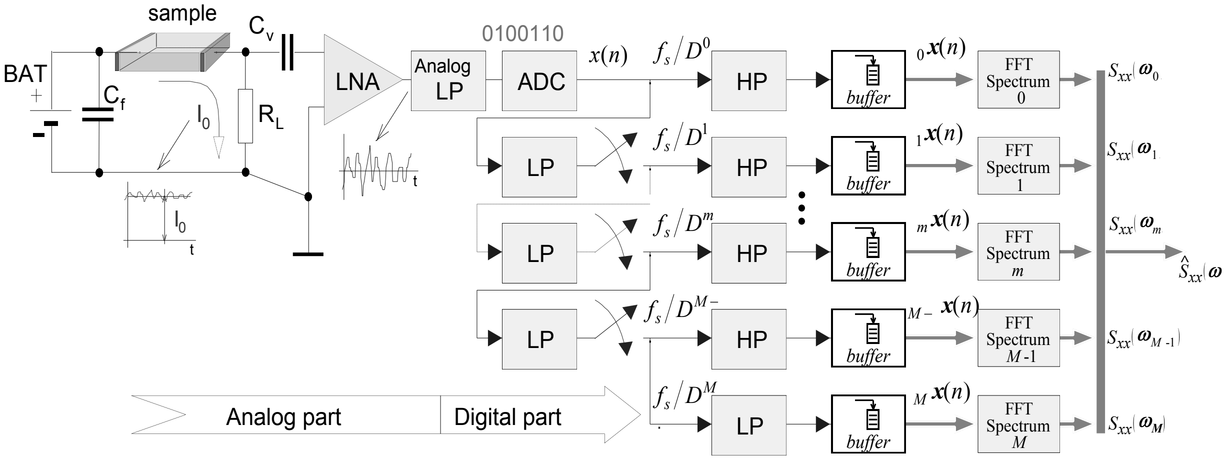

Fig. 2: A novel scheme for Power Spectral Density estimation using full parallel digital filter bank.

The computational algorithm designed with full parallel filter bank allows flexible and variable settings of band number and also simultaneously works in real-time. Splitting of the signal to frequency bands is provided through the conversion of sample frequency for each band and following filtration with high pass filter, with finite impulse response h_n and length N_h samples. If the sample frequency is decimated by factor D, frequency components of sampled signal must be higher than the value of nyquist frequency for each band suppressed by antialising low-pass filter, with finite impulse response h_d and length N_d samples. Cut-off frequency is equal to $f_{6dB} = f_S \cdot r/(2D)$, where the value of variable r is about r = 0,8. High-pass filter is then designed for the same cut-off frequency as a mirror to LP filter. Schematic diagram of FIR filter bank with down sampling is illustrated on fig. 2.

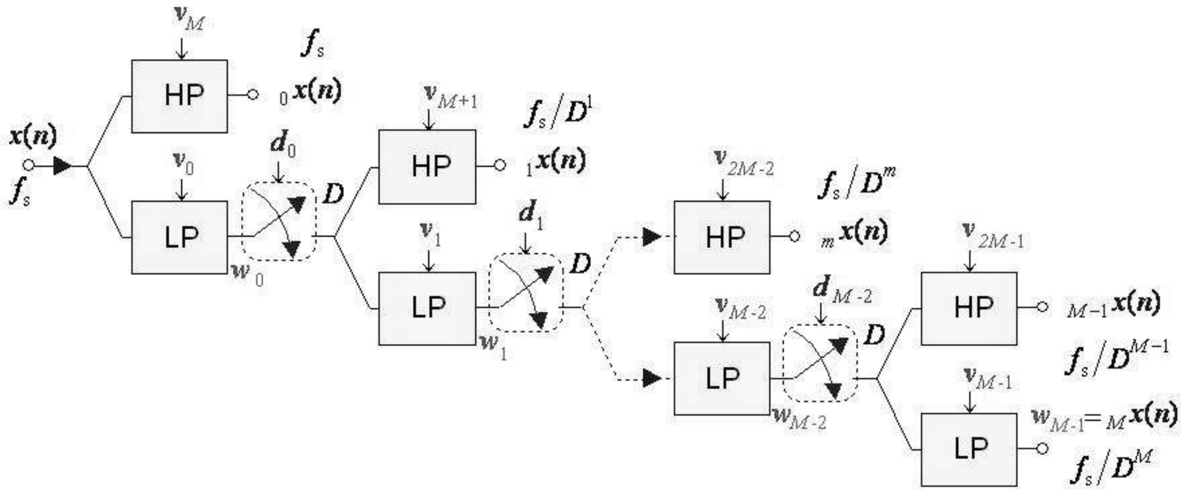

Fig.3. Schematic diagram of FIR filter bank with decimation.

Now, consider high pass filter with sample frequency f'_s. Transfer function responses to compressed modulation frequency characteristic of high-pass filter with sample frequency f_s.

$$ {}_mH(z) = \ldots \tag{1}$$

$$ z = \tag{2}$$

$$ {}_mH(e^{j\omega} \;) = \sum_{n=}^{N} \qquad e^{-} \tag{3}$$

By multiplication of gain characteristic of low pass filter and gain characteristic of high pass filter (suppressed D-times), we obtain band pass filter with sample frequency f'_s. Convolution as the mathematical operator in the time domain is equal to the multiplication in the frequency domain.

After decomposition process, we obtain sub-bands coefficients of applied transformation. The sum of total samples in each sub-band give us together double length than original samples length. During decomposition process we are computing PSD using Fast Fourier Transform (FFT) in each sub-band. This transformation is redundant and we can obtain good smoothed estimation of PSD and high resolution in low frequency area.

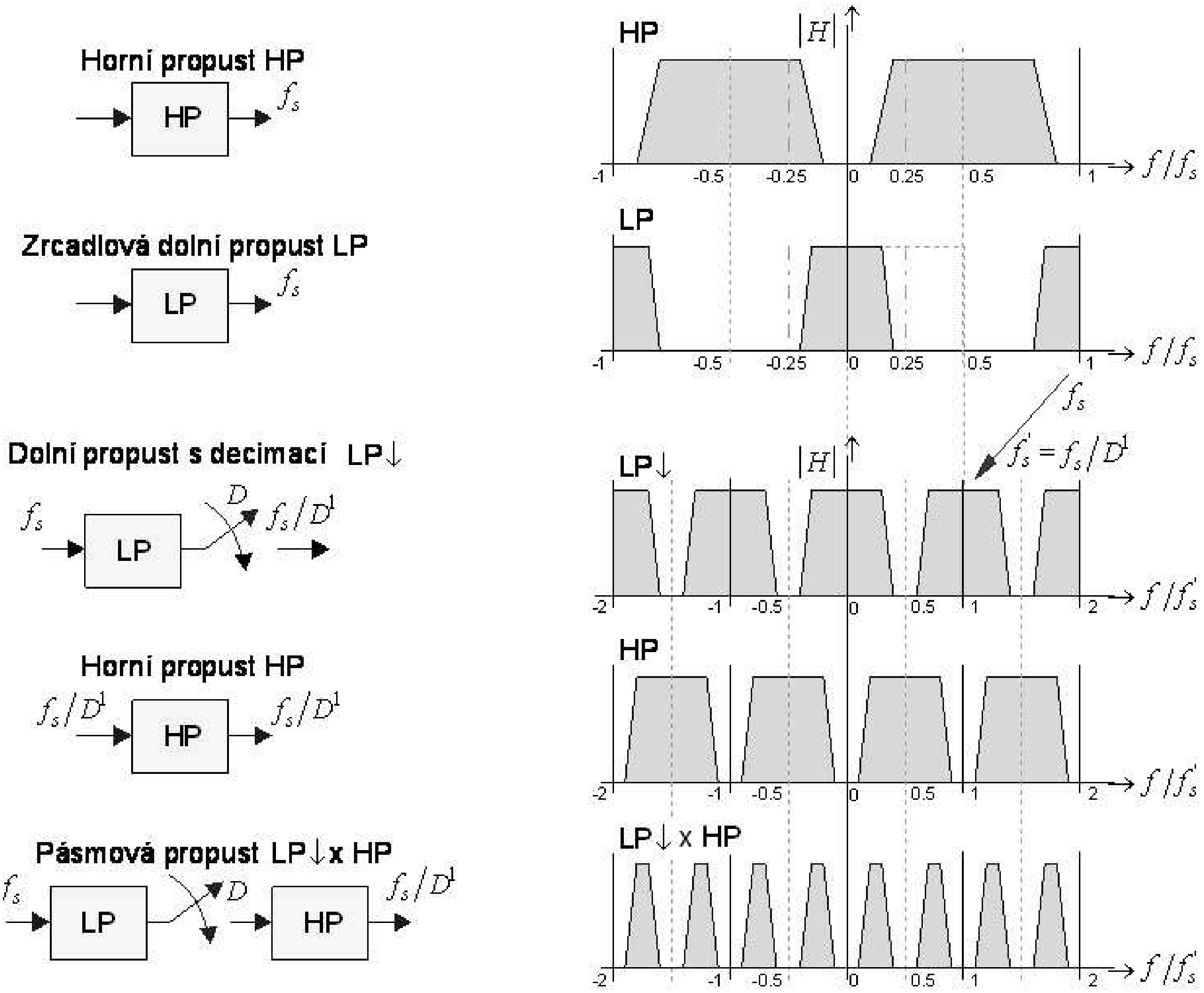

Fig. 4: An example of noise signal filter decomposition.

3. RESULTS

We have analyzed the long-term measurements of current fluctuations in MOSFET structure. Power spectral density is shown in fig. 4. This PSD spectrum consist the superposition between Lorenzian spectrum of G-R noise and 1/f low frequency spectrum. The power spectral density depends on frequency and temperature allows find out G-R time constant, activation energy, cross section of handhold the electron traps and recombination center and their concentration [2].

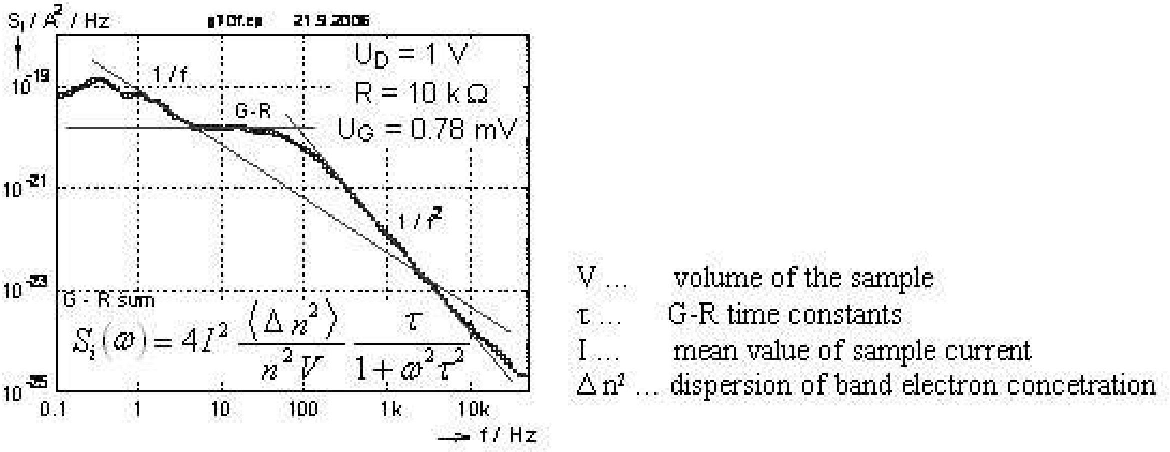

Fig. 5: An example of noise spectral density estimation for MOSFET transistor.

4. CONCLUSION

The noise spectroscopy is one of the promising methods used for determination of quality and reliability of semiconductor materials. In this paper, new approach of power spectral density estimation for wideband random process is presented. The algorithm was designed by octave digital bank filter and realized by fast fourier transform. Main advantages of proposed method are better resolution for very low frequencies and minimization of background noise for measuring setup. Shifting the low frequency noise analysis to submilihertz region improve characterization of quality and prediction of reliability for both active or passive components, e.g. MOS structures.

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