Noise in physical systems

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Ag. A. Ambrozy, Ed. *Proceedings of the 10th International Conference on Noise in Physical Systems, Including 1/f Noise, Biological Systems, and Membranes*, Budapest, August 1989, Akademiai Kiado, Budapest (1990).

This book contains a collection of papers (two to eight pages long) presented at 10th International Conferences on noise in different systems and materials. This conference was held on August 21 to 25, 1989 in Budapest. The next international conference on noise (these conferences occur every two years) will be held in Kyoto (Japan) in 1991. More than 100 scientists from 20 different countries participated in the 10th conference.

Fluctuations are of interest primarily because noise determines the fundamental thresholds for measuring and recording different physical quantities. In addition, by studying fluctuations in systems it is possible to gain a deeper understanding of the nature of the processes occurring in them. For this reason, interest in noise in physical, chemical, and biological systems has increased in the last few years. However, the section on noise in biological systems contains only two papers, by the American scientists L. J. De Felice and M. E. Green, in which fluctuations of the potential on a nerve membrane are discussed based on the Hodgkin-Huxley model. All other papers deal with noise in various physical systems, including crystalline and amorphous materials as well as electronic devices.

Attention is devoted primarily to one of the fundamental questions in physics—low-frequency noise with a $1/f$ spectrum. This problem is discussed in a review by Sh. M. Kogan [Usp. Fiz. Nauk **145**, 285 (1985)]. As before, the question of whether $1/f$ noise is a universal phenomenon or a specific property of a system remains open.

The works of C. M. Van Vliet and P. H. Handel on the theory of $1/f$ noise, based on the ideas of quantum electrodynamics, elicited great interest and discussion. P. H. Handel's works are devoted to the development of the $1/f$-noise quantum theory which he proposed previously. According to Handel, $1/f$ noise is related with the interference of wave functions describing the scattering of electrons. These functions differ by frequency owing to electron bremsstrahlung. Based on this, Handel formulated a many-body theory of $1/f$ noise (in terms of second quantization).

In his paper A. Van der Ziel compares the experimental data with Handel's theory of the Hooge constant, i.e., the constant α_H appearing in Hooge's formula for the spectral density of $1/f$ noise: $S_I/I^2 = \alpha_H/Nf$. The analysis was performed for a number of devices: vacuum photocells, pentodes, semiconductor resistors, field-effect and bipolar transistors, etc. It was found that for some devices the agreement between the experimental data and Handel's theory is very good, while for other devices there is a significant discrepancy between the theory and experiment. It is observed that in a number of cases the quantity α_H depends on the geometric dimensions of the sample and other structural parameters of the device.

V. Palenskis, Z. Sobliskas, and A. Stadalnikas show that the existence in semiconductors of large scale fluctuations of the potential could cause the constant α_H in Hooge's formula to take on large values. In his review T. G. M. Kleinpenning examines the theoretical and experimental results of investigations of $1/f$ noise in different types of electronic devices: *p-n* junctions, MOS and field-effect transistors, Josephson junctions, and Schottky diodes. He points out that the experimental data are mainly described satisfactorily by previously proposed theoretical models of $1/f$ noise. In this review, however, it is also stressed that Hooge's constant α_H is not universal and depends on the type and structure of the apparatus.

The book contains many papers on low-frequency noise in specific semiconductor devices: in GaAs films prepared by different technology (A. Ambrozy, *et al.*), Ge resistors (N. B. Luk'yanchikov *et al.*), long diodes (V. I. Stafeev *et al.*), Schottky diodes (H. H. Guttler, *et al.*), and Hall sensors based on superlattices (H. P. Baltes *et al.*); bipolar, field-effect, MOS, and NEMT transistors; and, other devices. Diverse mechanisms are employed and proposed to explain the intensity of the observed $1/f$ noise. Thus S. Decoutere *et al.* attribute the appearance of $1/f$ noise in bipolar transistors to surface recombination; J. Chang and C. R. Viswanathan explain $1/f$ noise in MOS transistors by the tunneling capture of current carriers on centers in a dielectric; and, S. Hashiguchi and H. Irie attribute $1/f$ noise in NEMT transistors to fluctuations of the carriers in the transistor channel.

The problem of $1/f$ noise in systems at thermodynamic equilibrium remains of great interest and elicits much discussion. In other words, can thermal Nyquist noise at low frequencies have a $1/f$ spectrum? There exist several models, according to which the answer to this question is, in principle, yes. L. N. Neustroev, V. V. Osipov, and O. Panashchenko show theoretically that thermal noise in a heterostructure with a transparent tunneling dielectric has a $1/f$ spectrum.

B. Orsal studied experimentally correlation in the double heterostructure $GaAs/Al_xGa_{1-x}As$. They found that the correlations reach a maximum near the threshold current for lasing and decay rapidly as the current is further increased. R. J. Fronen hypothesized that $1/f$ noise in laser diodes is related with spontaneous component emission.

A. J. Kil *et al.* studied fluctuations in devices based on the quantum Hall effect. The experiments were performed on a heterostructure. It was shown that the noise spectrum consists of two components. One component is independent of the frequency and is interpreted as thermal noise. The other component depends on the frequency and consists of two Lorentzian spectra whose time constants are equal to 1 and 10^{-2} s, respectively.

The relationship between $1/f$ noise and the theory of chaos and trubulence are studied in a paper by P. Handel. A special section is devoted to these last questions. The works contained in it are devoted primarily to theoretical and experimental investigations of chaotic oscillations in dynamical systems of different types. V. V. Gafiichuk, B. S. Kerner, V. V. Osipov, and Z. I. Vysynyuk examined the conditions and concrete mechanisms for the appearance of turbulence (space-time chaos), which are connected with the random appearance and disappearance of autosolitons in distributed nonequilibrium media (in the one-dimensional case—strata). Scenarios of the appearance of turbulence in a model of a nonequilibrium electron-hole plasma were studied numerically.

On the whole the papers in this book reflect the current status of experimental and theoretical investigations of noise in different systems. The book should be of interest to a wide range of specialists.

Translated by M. E. Alferieff