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MICROELECTRONIC DEVICES AND SYSTEMS

Integrated Circuit for Processing a Low-Frequency Signal from a Seismic Detector

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Abstract—Specific features for the detection and processing of a low-frequency signal from a seismic detector are considered in terms of an integrated circuit based on a large matrix crystal of the 5507 series. This integrated circuit is designed for the detection of human movements. The specific features of the information signal, obtained at the output of the seismic detector, and the main characteristics of the integrated circuit and its structure are reported.

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1. INTRODUCTION

At present, microsystems which perform signal processing with the transformation of physical quantities (TPQ) have become widely spread. With the use of such systems, various facilities for the detection and identification of objects are being developed. Facilities for detection using the seismic principle are based on an analysis of seismic perturbations of the ground caused by movement [1]. Miniaturization of the corresponding facilities for detection, the reduction of consumed power, and a decrease in the probability of false alarms represent the main tendencies in the field of security system design in Russia [2].

Specific features of such systems, algorithms for processing, and also their detailed description are not available in freely distributed publications. In the majority of contemporary foreign systems, an analysis of signals from the converter is performed using both hardware and software tools [3]. An improvement in the detectability of the facility when software tools are used brings about an increase in both the consumed and the area occupied by the facility on the crystal. However, in some cases, it is difficult to find a compromise solution to the choice of parameters and it requires the use of special algorithms for the processing of signals from a seismic detector without sacrificing the characteristics of a microsystem.

In this publication, we report on an integrated circuit (IC) which has been developed based on a matrix crystal of the 5507 series (BMK5507), performing the detection and processing of a signal from the seismic detector. A BMK5507 is a gate array of noncommutated elements, the electrical connections between which are provided by the metallization layer. Using BMK5507 ensures a significant decrease in the size of the detection facility and in the power consumption, and increases the reliability of the system. One of the main advantages of a large-scale IC (LSIC) based on BMK5507 is the possibility for the fabrication of both digital and analog circuits on the same crystal.

2. EXPERIMENT AND CALCULATIONS

The signal obtained at the output of a seismic detector is a random quantity, i.e., it is a temporal function, the value of which is unknown and can be predicted only with some probability. This is caused by the fact that amplitudes of the signals and phases fluctuate due to environmental conditions, to a variation in the source of seismic vibrations, and to other causes. As a result of this, the signal transferred to the electronic processing system is noise-ñontaminated to a large extent by the effect of various physical processes, which have a nondeterministic nature. The signal from a seismic detector provides information on the moving objects themselves and also on the characteristics of their motion (the speed of motion, and so on), on the distance of the source of seismic excitations from the detector, and on the nature of the ground, in which the seismic detector is installed.

In Fig. 1, we show the temporal shape of an input signal from the seismic detector; this shape is characteristic of a situation when a person walks past a seismic detector installed in the ground at a distance of 4 m from the person's path of movement. Figure 2 shows the spectral characteristic of the above signal.

The input stage of the IC is a differential operational amplifier stage composed of CMOS transistors. Its input resistance is 2 MΩ. This makes it possible to detect low-power signals from the input converter. Since the operational amplifier is set to a low consumption current, the cutoff frequency is 100 kHz.

The characteristics of the input signal are as follows:

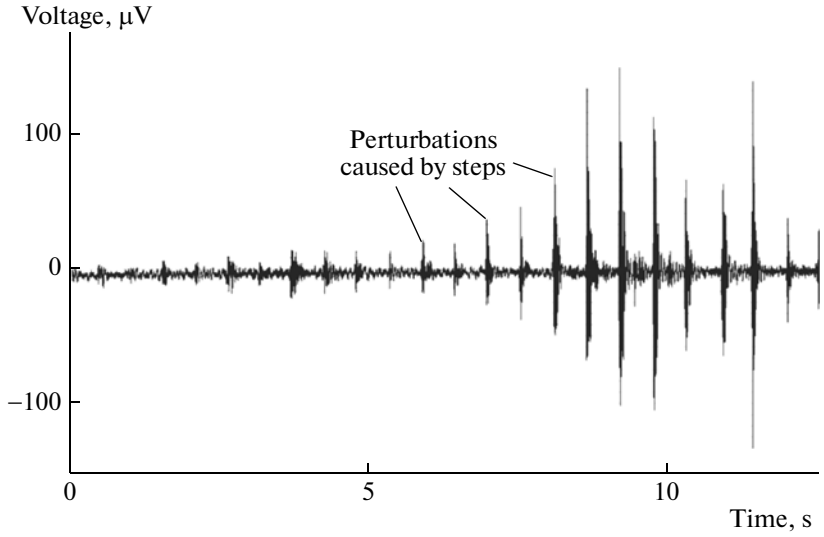

Fig. 1. Temporal shape of the input signal from the seismic detector in the case of a person walking.

(i) the root-mean-square value of the voltage (RMSVV) of noise at the output of the seismic detector is as large as 1 μV in the frequency range 10–150 Hz;

(ii) the RMSVV of a useful signal varies from 5 μV to 5 mV depending on the ground type, the physical characteristics of the moving object, and the distance separating the detector and the object;

(iii) the main energy of a person's steps is concentrated in the frequency range 70–110 Hz and, depending on different conditions (the ground type, the rate of motion, and physical characteristics of the person) can vary within the above range;

(iv) the input signal is regular, which distinguishes this signal from that generated by traffic or by exposure to natural sources of noise; and

(v) the duration of one step (as an impact on the ground) is in the range 0.09–0.2 s depending on the walking pace, and the duration of the pause between two steps is 0.3–0.6 s.

The necessity for the comprehensive consideration of the spectral and amplitude characteristics of the signal, its regularity, and temporal features brought about the use of special algorithms for processing the seismic detector's signal.

The integrated circuit based on BMK5507 includes the following two basic blocks:

(I) the seismic channel (it performs analog processing of the signal) and

(II) the logic block (it carries out the digital algorithm of processing).

The structure of the integrated circuit is shown in Fig. 3.

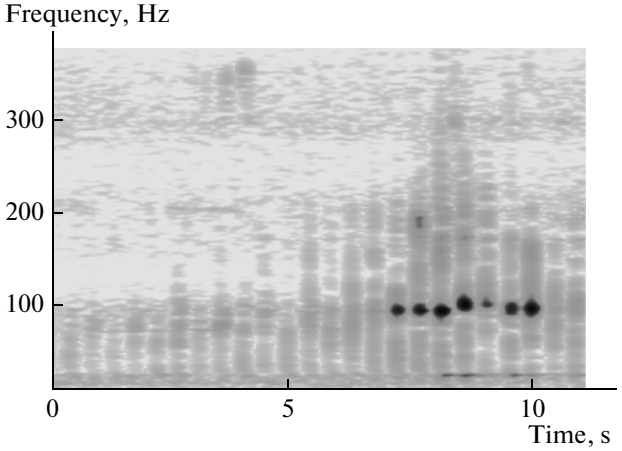

Fig. 2. The spectral–temporal characteristic of an input signal from the seismic detector in the case of a person walking.

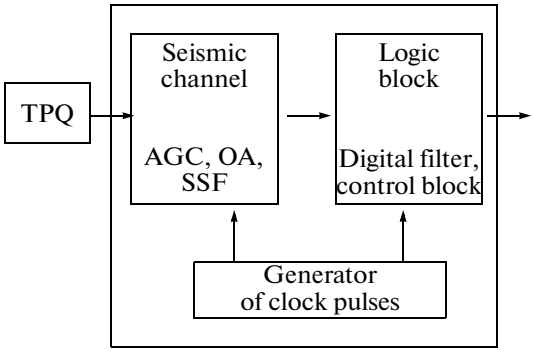

Fig. 3. The structure of an integrated circuit based on BMK5507: AGC is the automatic gain control, OA are operational amplifiers, SSF is the sampling and storage facility, and TPQ is transformation of the physical quantities.

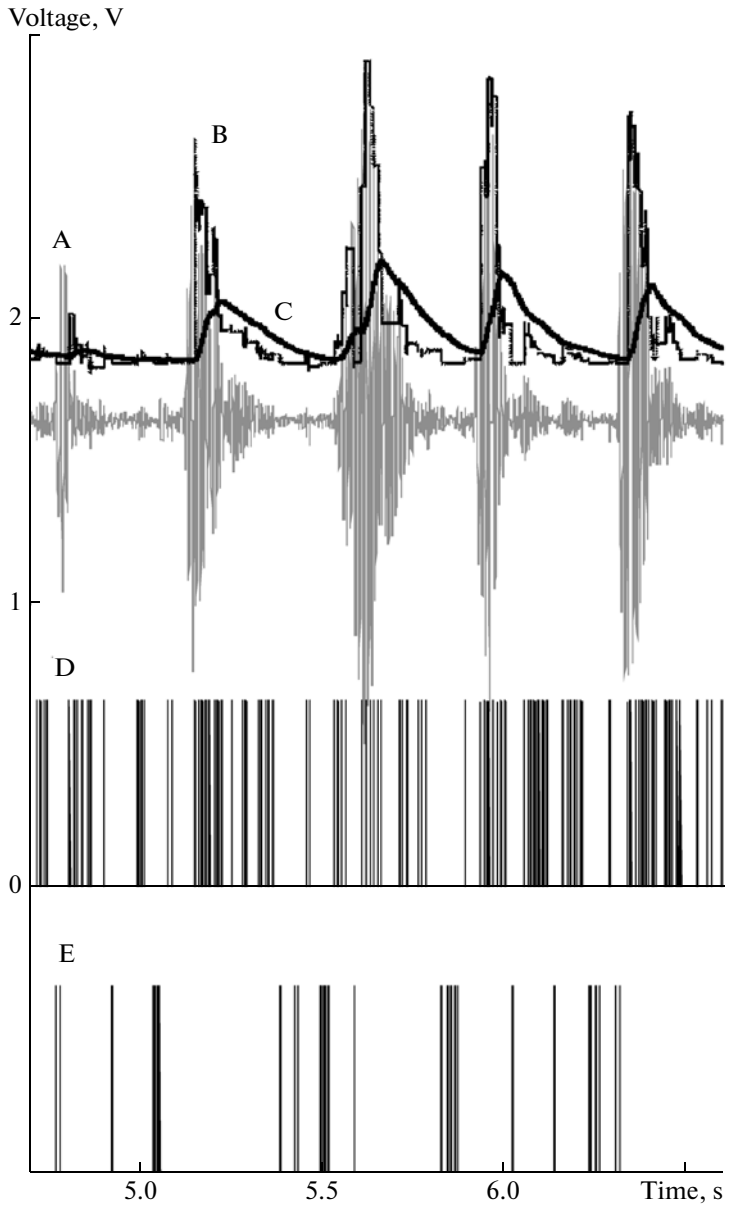

Fig. 4. A processing fragment of a signal from the seismic detector: A is the amplified signal from the seismic detector; B is the signal at the storage capacitance; C is the phantom signal; D is the recorded signal; and E is the clear signal.

Nine low-consumption operational amplifiers, implemented in the BMK5507 basis, are used in the seismic-channel block. These operational amplifiers perform the amplification, integration, and comparison functions.

In the seismic channel block, the signal from the seismic detector is subjected to filtration by a third-order active bandpass filter with a pass band of 70–110 Hz. The facility under consideration incorporates a circuit for automatic gain control, which makes it possible to control the natural seismic noise level and to extract the useful component of the signal. The total gain is as high as 6000; however, it can be increased to 20000. As a result of using low-consumption analog elements, the integrated circuit exhibits an intrinsic current consumption no higher than 200 μA.

The logic block performs digital filtration and control. The block includes a heuristic filter with an unconventional filtration algorithm, which makes it possible to preserve the advantages of digital filtration at limited hardware expenses compared to traditional filters with finite and infinite pulsed characteristics [4]. This algorithm is based on an efficient and simple approach to performance of estimation; this approach is based on the execution of experiments and the identification of general systematic features of an input signal obtained under different external conditions. The digital filter analyzes the temporal characteristics of

the signal and produces instructions for recording at the instant of time when the useful component of the signal attains a maximal value with interferences disregarded. The logic block produces instructions for the formation of a phantom signal, which is shown in Fig. 4.

The RC generator included in the integrated circuit makes enables tuning to the resonance frequency of the piezoelectric converter.

3. CONCLUSIONS

Thus, the developed integrated circuit for the detection and processing of a signal from a seismic detector within a facility enables the detection of a walking person at a distance of 5–10 m with a probability no lower than 0.95.

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