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New approach to the design of the multichannel analog processors

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Abstract

Experiments with application of calorimeters at modern colliders are conjugated with implementation of amplitude measurements over several thousands of electron channels . Similar situation is also typical for other areas of high-energy physics, e.g., in cosmic-ray experiments [1,2,3].

1. Introduction

Troubles with obtaining multi-channel processor for calorimeters trigger search for new techniques of multi-channel amplitude recording, such as the Monte Carlo technique as applied to autometry. Being, in essence, experimental, this technique can be used not only for simulation but also for solution of some problems of measurement, in particular, for digital measurement of the current pulse area. In the case of single-channel processing of simple-shape signals capabilities of the Monte Carlo technique are comparable with ordinary determined analogue-digital transformation. Advantages of the probability principle of measurements manifest itself under correlation-based measurements, measurements in presence of noises, as well as in multi-channel measurements, because in this case a multi-channel system can be constructed on a base of reliable digital microcircuits – logic elements, counters, comparators etc. At the KIPT laboratory of cosmic rays activities on investigation and development of the multi-channel stochastic processor (SP), based on the principles stated above, are undertaken.

2. Hardware

In Figures 1 and 3 the structural schemes of SP intended for digital measurement of pulse charges of ionisation detectors are presented. Figure 2 illustrates SP operation. The SP following elements are shown: the current-sensitive preamplifier (PA) [4], the voltage comparator (CV) the generator of random events (GRE), the “trial” counter (Ct), the “positive trial” counter (Cpt), the control unit (CU), the synchronisation unit (SU), the random pulse flow switch (SFS), the computer (PC). The following notations are used: Vx(ti) are input signals, Vr (ti) are supporting random pulses, Vxmax is the maximum level of the input signal, tN is the input signal duration, ix(ti) is the current input pulse, Vx(ti) is the voltage pulse that repeats a shape of the current input current.

Principally, SP operation is based on comparing the instantaneous values Vx(ti) of the envelope of the S-area input signals, obeying equal-probability distribution of random amplitudes Vr of supporting pulses, over the time interval tN in the comparator CV. As a result of comparison of each couple of values Vx(ti) and Vr(i), the comparator forms the binary value Z(ti) according to the rule:

$$Z(t_i) = \begin{cases} 1; & V_r(t_i) \le V_x(t_i) \\ 0; & V_r(t_i) > V_x(t_i) \end{cases} \qquad (1)$$

In the counter Ct a total number “N” of all trials for time tN is counted, whereas in the counter Cpt the number “n” of the trials performed for the same time but providing Z(ti)=1. As is follows from Figure 2, the n/N ratio determines the fraction of the area Sx of the measured pulse Vx(ti) to the area Smax=Vxmax*tN, i.e., probability for the random value of Vr(ti) to find itself under the envelope of the input signal Vx(ti), provided the probabilities of amplitudes Vr of random supporting signals generated in GRE are distributed uniformly. The probability is equal, approximately, to the signal area, i.e.

$$P\,[0 < V_r(t_i) \le V_x(t_i)] = \int_0^{t_N} V_r(t_i)\,dt \cong S_x \qquad (2)$$

The upper boundary of the dynamical range is determined by a value of Smax. The total mean square error of measurements depends of the trial number N and decreases as N increases. The number of digits for the counter Cpt is specified by a required measurement accuracy level. For instance, for inaccuracy 2 to 3 % the number of digits for the counter Cpt is estimated on a base N=16192.

In figure 1 a portion of the circuit inside a dashed line is commin for the entire multi-channel system. In every channel are left only PA, CV, Cpt and a number of logic elements, not depicted in the figure.

The most complicated unit of the system is GRE, capable to provide a flow of random supporting pulses of an equal-probability amplitude. In its design the principle of selection of the equal-probability temporal bands in the Poisson flow is used, for which the density of distribution of probability for occurrence of "n" pulses within the range of a length T equals:

$$f\ (T) = \lambda^n \quad \exp(-\lambda T) \qquad (3)$$

The probability for occurrence exactly "n" pulses in the tange T is:

$$P_n(T) = [(\lambda T)^n / n!]\ \exp(-\lambda T) \qquad (4)$$

The conventional density of the distribution of probability for occurrence of "n" pulses within the range of a length T under assumption that exactly "n" pulses find themselves in this range equals:

$$F_n(T) = f_n(T)\ /\ P_n(T) = n! / (T)^n \qquad (5)$$

Provided n=1, we obtain:

$$F_i(T) = 1 / T \qquad (6)$$

Thus, in this case (n=1) the density of distribution of probabilities for a random value is uniform within the range from 0 to N. It follows from Eq. (6) that if one fixes only coincidence of each first (n=1) random pulse of the simplest (Poisson) flow with period T, then he obtains succession of random pulses, distributed uniformly in time. In accordance with the principle stated above, the shaper of equal-probability time zones (SET), the principal element of GRE, has been developed. The GRE structural scheme is depicted in figure 4, along with: the white-noise generator (WNG) [5], the shaper of Poisson flow SPF, the shaper of equal-probability time zones (SET), the generator of periodical succession of T-intervals (GT), the unit of equal-probability amplitude pulses (EPA). Principal schemes for the units SET and EPF and the time diagrams of voltages in various points of the circuit are presented in figures 5 and 6.

References

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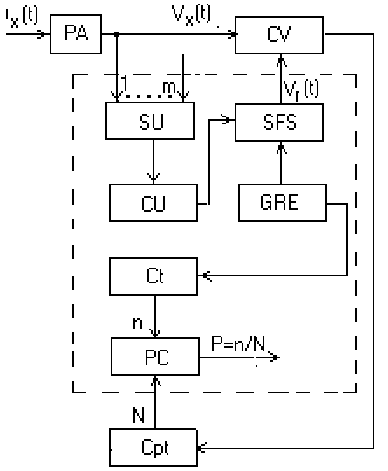

Fig.1. The structural scheme of the single channel of the multichannel stochastic processor.

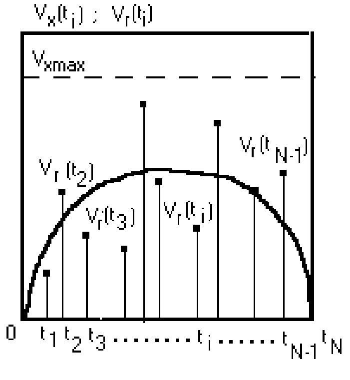

Fig2. The operation diagram of the stochastic processor.

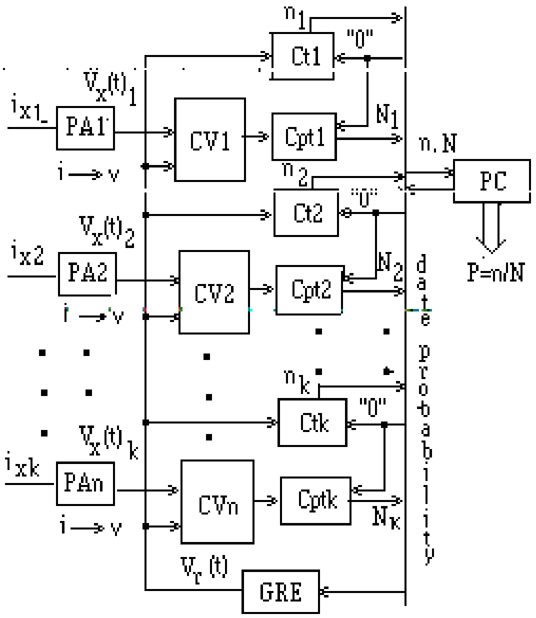

Fig.3. The structural scheme of the multichannel stochastic processor (SP).

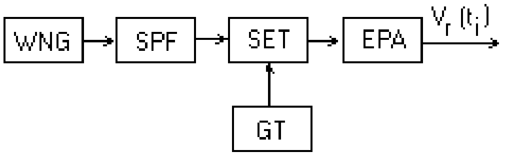

Fig.4. The structural scheme of the random events generator (GRE).

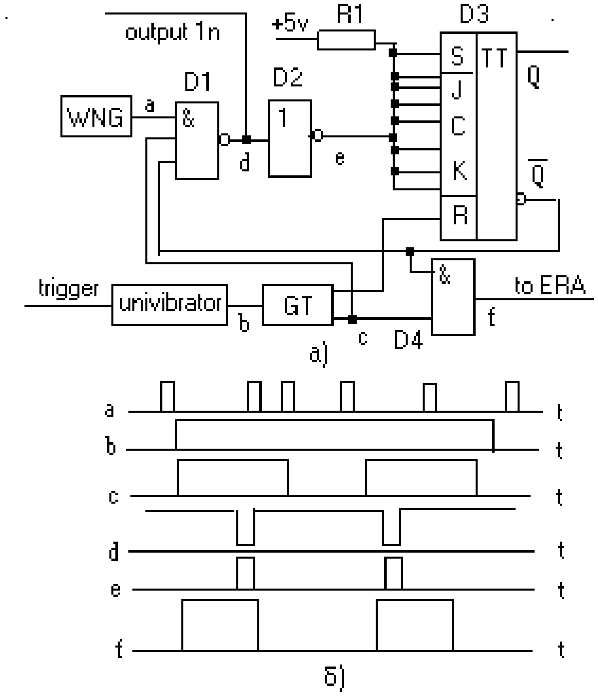

Fig.5. The shaper of the equal-probability time zones (SET).

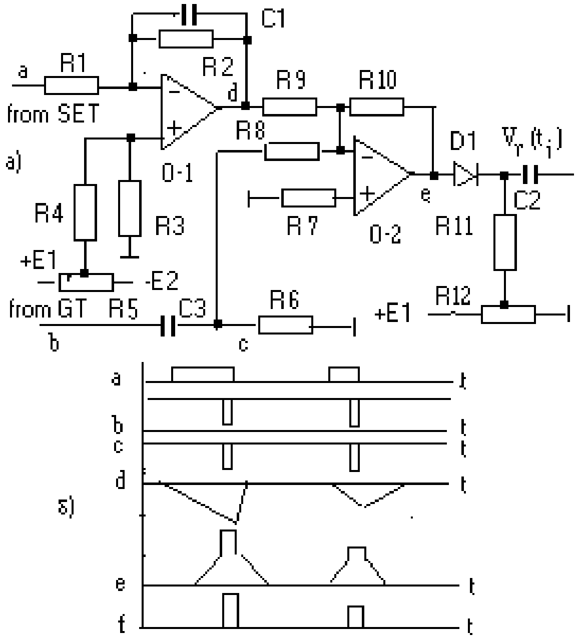

Fig.6. The unit of the equal-probability amplitude pulses (ERA).