

INTELLIGENT PROGRAMMABLE MEASUREMENT SYSTEM

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Abstract: The semantic redundancy decreasing sources totality self-programmable system is analyzed. The source flexible sampling program changing threshold value and the channel capacity demand equations founded. The software packet system realization was prepared and the operating simulation was made.

Keywords: measurement system

1 INTRODUCTION

The regular time division analog sources serving systems mainly satisfy frequency properties of the sources totality. But the channel capacity is using effectively only at the real and a priori suspecting object state coincidence. Actually, the object is remote, autonomy existing and precedent conditions are indeterminated.

So, the measurement information is statistically redundant. The data compression technique [1] using sometimes is not useful [2]. It is better to find suitable sources activity statistics estimation for the certain quasi-stationary interval, to follow interval changing movement and to realize its corresponding sampling.

2 SYSTEM OPERATING ALGORITHM

To satisfy the above mentioned item is possible by the self-programmable system using, which consist of the activity analyzing, the sampling program generation, the object behavior observing and control, the data frame compiling main units (Fig. 1).

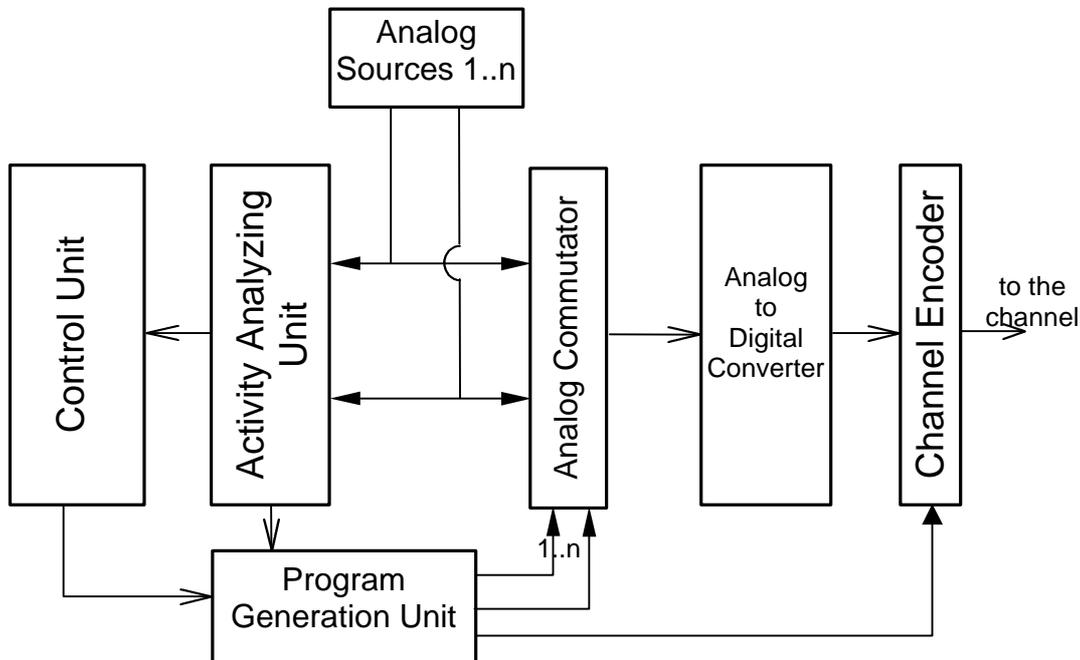


Figure 1. Intelligent programmable measurement system schematic drawing.

The activity analyzing unit is based on the adaptive commutation principle [3]. All analog sources are sampled at a constant rate with period T . In each sampling point an adaptive commutator chooses among total sources the most active one, i.e., the chosen source has the largest among other sources instant difference value, normalized with respect to its source analog measurement signal

mean-square deviation. The samples of the rest sources are supposed redundant. The i^{th} most active source sampling value takes place at the i^{th} memory cell for the next sample time comparison (Fig. 2), and the source activity manifestations N_i are indicated at the i^{th} counter. Remark, the i^{th} source normalized activity value $a_i = N_i/N$ ($N = \sum_i N_i \equiv T_a/T$, - the activity analyzing unit probes number at the analysis time T_a).

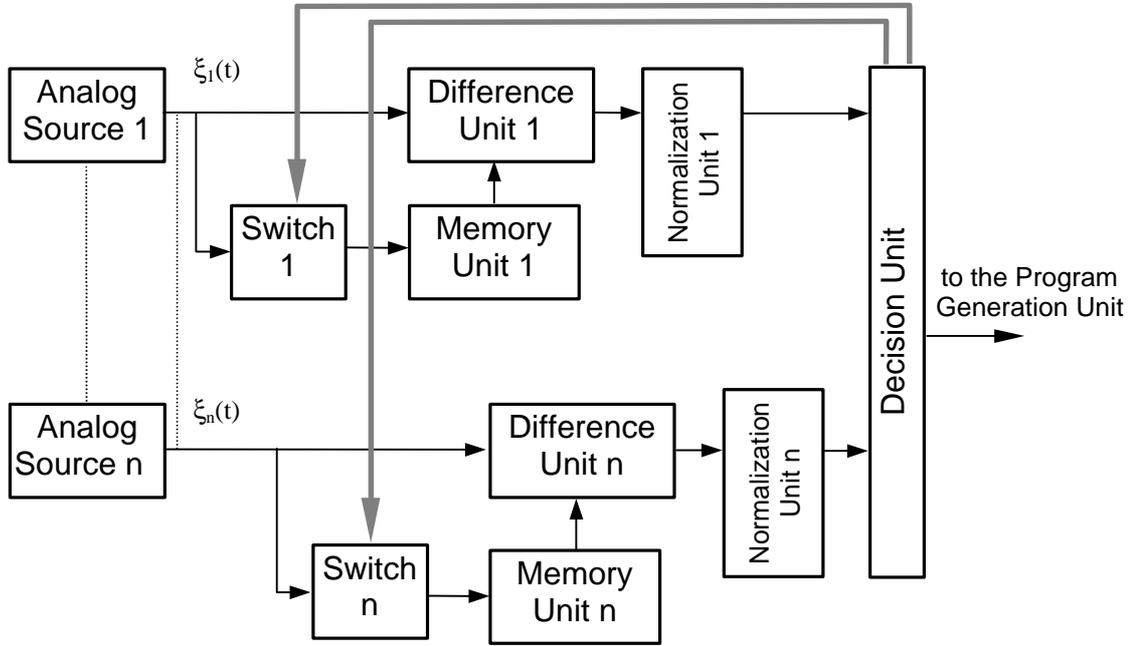


Figure 2. Activity Analyzing Unit schematic drawing.

Accordingly to the normalized activity, the i^{th} source samples number N_i appearance among N total samples probability is described by the binomial distribution

$$\Pr(N_i) = \binom{N}{N_i} a_i^{N_i} (1-a_i)^{N-N_i}$$

The i^{th} source activity indication number $\{N_i\}$ mean and the deviation values are as follow

$$\bar{N}_i = Na_i \text{ and } m_i = (\bar{N}_i - N_i)/N$$

$$s_i^2 = Na_i(1-a_i)/N^2 = \bar{N}_i(1-a_i)/N^2$$

The i^{th} source normalized activity estimation influences on the i^{th} sampling period determination precision, i.e. at the discretization error value. The Chebyshev inequality sets: the probability of difference between the random value and its mean value will be greater than some neglectfully small value e is less than the fraction with the mean deviation $D(x)$ as numerator and this value e in the second grade as denominator. So,

$$\Pr\left\{\left|\frac{N_i}{N} - a_i\right| \geq e\right\} \leq \frac{D(x)}{e^2} \text{ and } \Pr\left\{\left|\frac{N_i}{N} - a_i\right| \geq e\right\} \leq \frac{Na_i(1-a_i)}{e^2} = \frac{\bar{N}_i(1-a_i)}{e^2}$$

If the value e equal $3s_i$, then

$$\Pr\left\{\left|\frac{N_i}{N} - a_i\right| \geq 3s\right\} \leq \frac{s_i^2}{9s_i^2} = \frac{1}{9}$$

It means: more than deviations are scarcely probable. The fraction $\frac{W_i}{N}$ is unbiased and effective estimation of activity a_i .

Using Bernulli theorem and its Muavr-Laplace approximation, it is possible to find relation between the activity a_i , the guaranteed probability $\Pr\{x\}$ and the probes number N

$$\Pr\{|N_i/N - a_i| \leq \epsilon\} = 2F(t) - 1,$$

here $t = \epsilon \sqrt{N/[a_i(1-a_i)]}$, $F(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^t \exp\left(-\frac{x^2}{2}\right) dx$, ϵ - the neglectfully small value.

If the analysis time isn't too large, the i^{th} activity a_i is very small or very large, the Muavr-Laplace approximation can't be used. It is necessary to chose the i^{th} activity guaranteed interval corresponding with the guaranteed probability b . As the binominal distribution is asymmetrical and discrete, so the precise solution may be unreal and we take the less one. This interval depends on the probability value b and the probes number N [4]. As

$$\begin{cases} \sum_{m=N_i}^N C_N^m a_i^m (1-a_i)^{N-m} = \frac{1}{2}(1-b) \\ \sum_{m=0}^{N_i} C_N^m a_i^m (1-a_i)^{N-m} = \frac{1}{2}(1-b) \end{cases}$$

then for the certain guaranteed interval ϵ may be find the probes number N (Fig. 3).

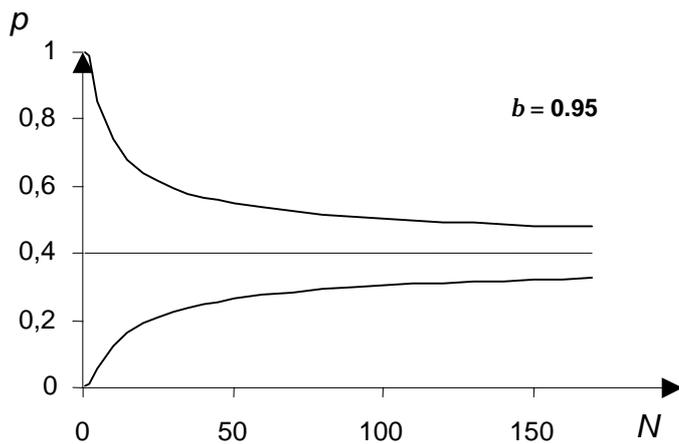


Figure 3. The i^{th} source normalized activity guaranteed probability estimation.

During the time T_a the current totality system sources activity distribution is formed at the n counters [5] and it is passed to the program generation unit. At the next analyzing steps this unit prepares the current sources activities estimation for the behavior observing and control unit.

The sampling frame for the certain quasi-stationary time interval is prepared after the received activity estimation by the program generation unit. It provides the each analog source uniform sampling due to the calculated activity estimation.

The sampling program generation unit determines the range between the smallest and the largest fractions and the activity multiplicities. Rounding off multiplicity number to the greatest integer this unit form their corresponding sources subgroups.

The each subgroup sources number is connected with the multiplicity sampling number through the system informative possibility $I = \sum_j a_j F_j$, the sampling access cycle $C = 1/F_{\min}$, the sampling field columns and rows number: $l = 1/F_{\max}$ and $r = l/I$, accordingly (here a_j and F_j - the j^{th} subgroup sources number and it's frequency, accordingly; $F_{\min} = \min\{F_j\}$, $F_{\max} = \max\{F_j\}$, $F_j = N_j/T_a = a_i/T_k$, T_k - the activity analysing unit time period).

The j^{th} subgroup sources access period $n_j = F_{\max}/F_j$ rows. Such sampling program algorithm provides the channel capacity optimal using.

At the same time, the behavior observing and control unit checks the object state. It is realized through the comparison the known threshold value and the evaluated summarized deviations between the program set predictive and real current activities at the certain analyzing interval.

Just as this variances $x_i = (N_i - N_{iu})/N$ sum is probable and for the great sources number n the sum probability distribution may be presented as the normal distribution with parameters $m = \sum_i m_i$

and $s = \sqrt{\sum_i s_i^2}$, here m_i and s_i - the i^{th} source mean and mean square samples variance deviation.

Then the threshold value.

$$x_g = \pm k_g s = \pm k_g \frac{1}{N} \sqrt{\sum_i a_i (1 - a_i)} = \pm \frac{k_g}{\sqrt{N}} \sqrt{1 - \sum_i a_i^2}, \quad i = \overline{1, n}$$

here k_g - the known guaranteed coefficient.

The threshold value excess is the investigated object circumstances changing evidence. It indicates at the next formation necessity. This new activity distribution is find by the analyzing unit again. As the object properties are not known enough well, the sampling program has to change due to the current totality sources activities analysis results on the object certain phase function [6]. It makes system more intelligible and autonomous.

The frame compiling unit realizes the measurement data analog to digital conversion, the data and the activity distribution error correction coding, its' transmitting once at the quasi-stationary interval duration [7].

These units operations are realized as the software through the program packet number.

3 RATE DEMANDS ESTIMATION

The total analog sources serving system error consists of the instrumentation, the discretization, the quantization and the link noise influence components.

The relative mean-square discretization error estimation

$$d_d = \frac{1}{\sqrt{3}} (w_{1i} T_{oi}) \quad (1)$$

here w_{1i} and T_{oi} - the i^{th} source mean-square frequency and sampling time period, accordingly.

The relative mean-square quantization error estimation

$$d_q^2 = \frac{1}{12} \left(\frac{\Delta U}{s} \right)^2 = \frac{s^2}{12 \cdot 4^{m_i}} \quad (2)$$

here m_i - the measurement data binary symbols number, s_i - the i^{th} source mean-square deviation, ΔU - the absolute quantization step value, s - the analog measurement signals guaranteed probability coefficient.

The fluctuation noise in the link can lead to mutilation the measurement data in the binary symmetric channel [8]. Let's suppose, the synchronization is reliable and correct, and sync word per one sample has dimension m_s binary digits. If to have in mind parity check coding and to use the wrong code words erasing [9] with probability P_i , the link noise influence error can be considered as some accumulated discretization errors random number k with geometric distribution

$$P(k) = P_i^k (1 - P_i)$$

here $P_i = 1 - (1 - p)^{m_i} \approx p(m_i + 1)$ - the loss sample probability equal to the wrong code word receiving probability due to parity check decision; m_i - the word symbols number, p - the binary digit error probability.

Hence, the relative mean-square loss error estimation

$$d_i^2 = \frac{1}{s_i^2} M \left[\sum_{k=0}^{\infty} \left(\sum_{c=0}^k Z_{gi} \right)^2 (1 - P_i) P_i^k \right] = d_d^2 \frac{P_i(1 + P_i)}{(1 - P_i)^2} \approx d_d^2 P_i = d_d^2 \rho(m_i + 1) \quad (3)$$

The total relative mean-square error estimation is obtained after expressions (1)- (3)

$$d^2 = d_i^2 + d_d^2 + d_q^2 + d_i^2 = d_i^2 + \frac{1}{3} (w_{1i} T_{oi})^2 [1 + \rho(m_i + 1)] + s^2 / (12 \cdot 4^{m_i}) \quad (4)$$

The i^{th} source sampling time period

$$T_{oi} = \sqrt{3} \frac{1}{w_{1i}} \sqrt{\frac{d^2 - d_i^2 - s^2 / (12 \cdot 4^{m_i})}{1 + \rho(m_i + 1)}} \quad (5)$$

The expression for the data rate estimation R as inversely proportional value to the symbol time duration t was found using sampling component (1) of the full mean-square error estimation (4). As the i^{th} source intensity $I_i = 1/T_{oi}$, hence the time division multiplex system commutator switching time

$$T_k = 1/I_c = 1 / \sum_{i=1}^n I_i = \left[\sum_{i=1}^n 1/T_{oi} \right]^{-1}$$

Taking in considerations the same quantization, instrumentation and total error values for all system sources and $T_k = (m_i + m_s + 1)t$, (here m_s - the sync word per one source symbols number, t - the binary symbol duration), the rate demands estimation normalized with respect to the totality mean-square frequency w_{Σ} is

$$\frac{R}{w_{\Sigma}} = \frac{\sqrt{2 + \rho(m_i + 1)}}{\sqrt{3(d^2 - d_i^2 - s^2 / (12 \cdot 4^{m_i}))}} (m_i + m_s + 1) \quad (8)$$

here d - the admissible relative mean square reconstruction error value and $w_{\Sigma} = \sum_i w_{1i}$.

4 CONCLUSIONS

The simulation results of the measurement system operating confirm declared proposals as well.

REFERENCES

- [1] T. Cover, J. Thomas, Elements of Information Theory, John Wiley & Sons, Inc., New York, /Chichester / Brisbane / Toronto / Singapore, 1991, 542 p.
- [2] Yu. Vasylyk, O. Ivakhiv, The measurement-computer network terminal organizing manner comparison, The Lviv Polytechnic State University herald no. **283** (1994) 66-74 (in Ukrainian).
- [3] I.D. Kalashnikov, V.S. Stepanov, and A.V. Churkin, Adaptive Data Gathering and Transmission Systems, Energiya Press, Moscow, 1975, 240 p. (in Russian).
- [4] E. Ventsel, The probability theory, Moscow, Physmathgiz, 1962, (in Russian).
- [5] Data compressor. Patent USA 31369.222, 340 - 172.5.
- [6] USSR Patent # 650240.
- [7] O. Ivakhiv, Measurement Information Enumerative Source Coding, Kontrolno-vymikyvalna tehnika **50** (1993) 21-32, (in Ukrainian).
- [8] O. Ivakhiv, A. Karlov, V. Cherkasov, Influence of the channel on continuous message transmission quality in adaptive data transmission systems, Radioelectronics and Communication Systems **20** (3) (1977) 8-15
- [9] I.M. Teplyakov, I.D. Kalashnikov, and B.V. Roshchin, Satellite Data Transmission Radio Links, Sovetskoe Radio Press, Moscow, 1975, 400p. (in Russian)

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