УДК 621.396

TO INFORMATIONAL PROVIDANCY OF MODULE PROJECTING OF RADIO-ELECTRONIC MEANS

A.A. Zotov[1], V.A. Zotov[2]

Department "Design of Radioelectronic and Microprocessor Systems", TSTU (1); 13th State Scientific-research Institute Ministry of Defence, Moscow (2)

Represented by Member of Editorial Board Professor Yu.L. Muromtsev

Key words and phrases: electronic module; module radioelectronic system; entropy of module system; modules typesize; compatibility of modules; module unification.

Abstract: Among the radioelectronic means projecting modules are more and more widely used. On the basis of formalized introductions of module systems the entropy principle of the module projecting is examined in the paper. Its application reduces the time requires for its development, regulation, modernization and restoration of the radio-electronic means.

Symbols

D – module multitude of definite level;
d – number of module typesizes;
E – vector space of modules;
H – module system entropy;
I, J – set of modules possessing mutual compatibility;
L – multitude of all combinations;
P – probability of using the definite typesize module;
R_f – multitude of connections in module system;
r_y – connection allowing to realize exchange of information (power) between modules for functional interaction;
S – module radio-electronic system;
S_f – variant of module system construction;
$\hat{S}$ – module system standard nuclear;
$\tilde{S}$ – module system specialized nucleus;
$T(P_i)$ – demands for electronic arrangements;
V_i, V_j – directly connected modules between which information or power is realized;
$\bar{X}$ – typesize vector.

Abbreviations

IMS – integrated microscheme;
MS – microscheme;
RED – reserve equipment and devices;
REE – radioelectronic equipment;
REM – radioelectronic means;
RES – radioelectronic system;
SEM – standard electronic module;
TV – television.

Module constructions and their formalized introductions

The row of directions based on the use of electronic modules has been outlined in the home and foreign practice of projecting of REM. Electronic module is understood as functionally and constructively complete arrangement, realizing the definite special function (processing of information, transformation of power etc.) which don't have independent means and serve for completing set at REM projecting. The use of modules allows realizing REM unification effectively, i.e. driving goods to unified patterns based on the rational amount and variety.

Since the electronic modules aren't used for specific purposes, their application suggests the creation of special RES. Module RES is made of requital connected modules V_i, V_j with given topology connections r_{ij} destinated for solution of definite set of targets [1, 2]:

$$S = \{< V_i , r_{ij} , V_j >\}; \; i \neq j, \; j \in I .$$

The connection r_{ij} should be to understood as means (and its parameters) allowing to realize an exchange with information or power between modules for their functional mutual action. The connections can be horizontal r_y^h —between the modules of the same level and vertical r^v — between the modules of the different level of complexity. I, J is a set of the suitable modules; i, j — their elements. The multitude itself is represented as a regulated triad$<V_i, r_{ij}, V_j>$.

In such understanding of the radio-electronic system it can be considered as an aggregate of mutually connected modules where any variant of module system construction S formally can be interpreted as a point of a vector space $E \in S$, i.e. including into itself all the variants of separate modules combination. Then it is logical to set topological order determining the consequence of the processes execution in the module system. At first a module "sum" forming the triad is determined (V_i, r_{ij}, V_j):

$$V_i \oplus V_j, i \neq j, Vi, Vj \in E, i, j \in J.$$

This sum determines a connected pair of the modules V_i and V_j. Then the elements of the multitude $S = \{V_i\}$, $i \in E$ are multiplied on natural numbers $\alpha_1, \alpha_2, \ldots, \alpha_l, \ldots \alpha_k$:

$$\alpha_l Vi \in E; \alpha_1 \geq 0; i \in J.$$

Here $S = \{V_i\}$, $i \in E$ — is the modules connection possessing mutual compatibility of all the modules. At last the multitude of the connections R_f in the module system S is

$$R_f = \left\{ r_{ij}^f \right\}, i, j \in J.$$

This multitude has a limitation: not all combinations are admitted but modules containing the least complication and connections for realization of the system aim function, for example the function of quality $\varphi(X_j)$.

Thus the multitude of the all combinations

$$L = [\alpha_1 V_1 \oplus \alpha_2 V_2 \oplus \ldots \underline{\oplus} \; \alpha_e V_i \ldots \subset E, R_f];$$
$$\alpha_2 \geq 0; \; e = \overline{1,k} ; \; i \in J,$$

which defines a collection of variants for constructing of the module systems of given functionality.

The sequence $V_1, V_2, \ldots, V_e, \ldots, V_i$ scopes all the module types as functional and constructive units. The numbers $\alpha_1, \alpha_2, \ldots, \alpha_e, \ldots, \alpha_i$ appoint to the quantity of specific modules. Common sum of multiplication of the multitudes as points is included into vector space E where the links R_i are the vectors. Module construction for one of the TV set "Record" variants is shown on the table 1. Zero level — micro-scheme is taken as base.

The table 1 shows that the modules unification utterly is absent, and for micro-schemes is about 18%.

The module system synthesis would be its creation by means mainly from the standard modules possessing functional and geometry mutual replaceability. However module system can consist of the standard and specialized modules. The multitude of the standard modules $\{\hat{V}_i\}$ consists of the standard nucleus of the module system S:

Table 1

Module Construction without Unification

Module prescription	Mark	Type of MS (in Russian)	Base module level	
			Number of MS	α
Synchronization and horizontal line	V_1	К174АФ1А	1	$\alpha_1 = 1$
Automatic arranger of intermediate influence	V_2	К224УР3	2	$\alpha_2 = 2$
Intermediate sound frequency amplifier	V_3	К174УР1	1	$\alpha_3 = 3$
Sound power amplifier	V_4	К174УН7	1	$\alpha_4 = 4$
Brightness of the channel and matrix	V_5	К174АФ4А	1	$\alpha_5 = 1$
Color signal detector	V_6	К174ХА1	2	$\alpha_6 = 1$
Processing of the color and identify signals	V_7	К155ТМ2	1	$\alpha_7 = 1$
	V_8	К195ЛА3	1	$\alpha_8 = 1$
Intermediate image frequency amplifier	V_9	К174УР2Б	1	$\alpha_9 = 1$

$$\hat{S} = \left\{\hat{V}_i\right\} \subseteq S = \{V_i\},\ i \in J,$$

i.e. the standard modules are the part of the common number electronic modules.

The specialized part of the module system is under-multitude

$$\tilde{S} = \left\{\tilde{V}_j\right\} = \{V_{ij}\} \setminus \left\{\tilde{V}_j\right\}, j \in J.$$

It is difference of the modules multitudes $\{V_j\}$ and modules non-possessing to the multitude $\{V_j\}$, i.e. $\{\tilde{V}_j\}$.

Entropy Principle of Module Projecting of Radio-electronic means

Practice of projecting radio-electronic means shows that when produced goods are often changed, decisive conditions for assimilation of new radio-electronic arrangements and application of the most economical methods of their production as well as their standardization is the unification, i.e. the reduction of the typesize number of modules for the same functional purpose. The unification allows using the level structure and finding a reciprocal link of the modules upon the levels. The levels themselves will be the multitudes at which the module multitude D_r of the underlying level enters the modules multitude of the higher level. At the level structure the dependence of the modules makes a vertical:

$$D_1 \supset D_2 \supset \ldots \supset D_p,\ r = \overline{2, p}.$$

In this vertical D_1 is the multitude of the oldest level, which includes the multitude D_2; D_r is the multitude including the multitude underlying and simultaneously entering

the multitude of higher level. Obviously that such hierarchical multitudes dependence reflects reciprocal link according to their level change: $r=\overline{2,p}$. The maximum level D in the hierarchy multitudes determines module level of radio-electronic system. Module system S represents the maximum level in the hierarchy of the possible functional modules.

Likewise, the module dependence along horizontal and vertical can be presented for each r-th hierarchy level with unit:

$$D_r = \bigcup_{g=1}^{d} D_{rg};\ g=\overline{1,d}.$$

Here $g=\overline{1,d}$ is the module number on r-th level. The procedure of unification consists of belonging of the module to the level r and to typesize g; d is the typesize number.

Such representation of the module system reveals the indefinity of the variety of modules forming the system. This circumstance allows using an informational approach, i.e. according to Shannon's formula it allows estimating the modules variety in the system – entropy H:

$$H = \sum_{g=1}^{d} P_g \log_2 P_g$$

If entropy H describes the indefinity, i.e. the module typesizes variety, then the value P_g represents the relation of the g-th module typesizes repetitiveness to the sum of all module typesizes d repetiveness. The typesize is understoond as the vector

$$\bar{X} = \{X_j\},\ j = \left[\overline{1,m}\right],$$

composite parts of which are values m parameters representing this module in the system with enough precision [1].

Entropy interpretation of module system suggests the following conclusions:

1. If module is characterized by one main qualificatory parameter, then the typesize vector is degraded into scalar.
2. Entropy of the whole regulated system possessing the module of the same typesize (d = 1) equal zero. In this case $P_1 = 1$; $P_2 = P_3 = \ldots = P = 0$; $\lim\limits_{p\to 0} p\log_p = 0$.
3. The module system entropy takes maximum value when all module typesizes are used only once, i.e. modules of the all levels are individual:

$$D_{r1} \cap D_{r2} = \varnothing;\ D_{r2} \cap D_{r3} = \varnothing;\ \ldots;\ D_{r(d\text{-}1)} \cap D_{rl} = \varnothing$$

It is obvious entropy is

$$H_{\max} = \sum \frac{1}{d} \log_2 \left(\frac{1}{d}\right) = \log_2 d,$$

i.e. maximum.

Therefore the entropy of the module system S including d variants of separated modules is in the limits

$$0 \le H(S) \le H(S_{\max}) = \log_2 d.$$

The right part of this expression is the value of module variety. Consequently, entropy is a measure of module non-regulativeness of radio-electronic system and can

change from zero to whole variety. This consideration is important for the proportion definition of the elemental base of the RES production and forming of RED.

While projecting the module RES the electronic module compatibility has great significance, i.e. module property defines a possibility of the organization of direct interacting with the delivery of the type and unification of the connections r_{ij}. The following compatibilities: constructive, electrical, electromagnetic, informative and leveler [1] are distinguished.

Constructive compatibility is the modules' property determining the possibility of their joint use and constructive replaceability.

Electrical compatibility determines the possibility of energetic interaction of modules for their conjoint use. All the multitude elements can be: the voltage of a source; the amplitude of out signals; the range of allowed fluctuations; frequency descriptions of signal circuits; a load coefficient at input and output etc.

Electromagnetic compatibility characterizes the possibility of successful functioning of the modules in the module composition in conditions of mutually created or the electromagnetic field.

Information compatibility is the attribute of modules to interact functionally at some final multitude states of processes or module structure with decrease of uncertainty of the states or processes connecting the source with the user. The multitude elements can be methods of representation, storage, transmission, processing and control of information. They are means of coding, speed of information transmission, structure of informative words etc.

Level compatibility is the degree of coincidence of the functionally interacting modules V_i and V_j.

At allowed compatibility of radio-electronic arrangements the entropy of their family $H(\alpha)$ with one functional appointment can be defined as

$$H(\alpha)=\sum_{\alpha=1}^{t} H_{\alpha}(S)=\sum_{\alpha=1}^{l}\sum_{g=1}^{d} P_{\alpha g}\log_2 P_{\alpha g}\ .$$

Here, the attribute of the entropy addition is taken into account; $\alpha = 1, 2, \ldots, g$ – the system number in the family.

Let's demand to select among TV sets the most suitable one for the creation of new TV sets [3]. Analyzing preceding patterns, for example, TV set "Рекорд ВЦ-311" (in Russian) as the goods of middle complexity possessing the average functional number between the most and the least meanings. As basic construction at the first stage is the module of zero level - the integrated micro-scheme.

Analyzing the table 1 from the modernization position it can be noted:

1. The function of the intermediate frequency image amplifier (MS К174УР2Б), the intermediate frequency audio amplifier (MS К174УР1), automatic tuning up of heterodyne frequency (MS К224УР3) can be carried out by the arrangements on micro-schemes series К174УР10 — a widestreap amplifier.
2. The cadre synchronization can be executed on the specially selected for this aim micro-scheme К174ХА24 — synchronization of line and cadre scanning.
3. The micro-scheme functions К174АФ1 (synchronization of the oscillator of the line scanning) will be passed on the micro-scheme К174ХА24 (of line and cadre synchronization).
4. The cadre scanning oscillation can be fulfilled on the MS, for example, series К174ТЛ.

After the transformation the table 1 has got a new look (table 2).

According to the table 2 unification has already increased to 40 % an this stage, i.e. unregulated remains are $L = \alpha_N/N = 6/10 = 0{,}6$.

Table 2

Module Construction with Unification

Module prescription	Mark	Type of MS (in Russian)	Base module level	
			Number of MS	α
Oscillator synchronization of the line and cadre scanning	V_1	К174ХА24	1	$\alpha_1 = 1$
Oscillator of the cadre scanning	V_2	К124ГЛ/ГЛ1А/ГЛ2	1	$\alpha_2 = 1$
Amplifier of intermediate frequency of the image	V_3	К174УР10	1	$\alpha_3 = 4$
audio	V_3	К174УР10	1	
automatic tuning up of the heterodyne frequency	V_3	К174УР10	2	
Amplifier of audio power	V_4	К174УН7	1	$\alpha_4 = 1$
Processing of the color and identification signals	V_5	К155ТМ2	1	$\alpha_5 = 1$
Oscillator of commuting impulses	V_6	К195ЛА3	1	$\alpha_6 = 1$

Allowed variants of unification must satisfy to certain demands $T(P_i)$, $\forall P_i \in Q$. Here P_i is the list of radio-electronic arrangements on which accepted decisions for unifications are spread (in given example TV sets). For all that accepted decisions $\forall p_i \in Q$ spread on all the arrangements (p_i), i.e. they refer to group Q, which is the multitude

$$Q = \{p_1, p_2, \ldots, p_n\} = \{p_i\}, \quad i \in \overline{[1,n]}.$$

Here p_i is a system (i — whole number).

Obviously any module system S_f can be represented in the following view:

$$\forall S_f \in L = \hat{S}_f \cup \tilde{S}_f \left| \begin{array}{l} \hat{S}_f \subseteq S_f, \\ \tilde{S}_f \subseteq S_f, \\ \hat{S}_f \cap \tilde{S} = 0, \\ R_f = \{r_{ij}\}, \ i,j \in J. \end{array} \right.$$

Here record $\forall S_f \in L$ defines the position that module system S_f is the part of all collections of the allowed variants possessing attribute of the module systems for given appointment. Standard nuclear of the module system $\hat{S}_f$ and its specialized part $\tilde{S}_f$ possess one of the properties $\hat{S}_f$ or $\tilde{S}_f$ (recorded as $\hat{S}_f \cup \tilde{S}$). It makes all four variants possible. *In the first* variant all the standard modules are kept in the system S_f, i.e. in the concrete modules aggregation destined for decision of given kind of tasks in accordance with the type and purpose of the system ($\hat{S} \subseteq S_f$). A case $\hat{S}_f = S_f$ is

possible if the whole system consists of the standard modules. *In the third* case recording $\hat{S} \cap \tilde{S}$ is an empty multitude, i.e. the modules are not standard and not specialized. *In the fourth* case the value $R_f = \{r_{ij}\}$, $i, j \in J$ characterizes the aggregation of interconnected modules in the uncrossing multitudes $\hat{S}$ and $\tilde{S}$ of the united catalogue.

For such module system structure the task of the unification as the optimum choice of the arrangement variant can be formulated as follows [1, 3]:

$$\text{extr}\varphi(\alpha) = \sum_{i=1}^{n} \varphi_i(\alpha_j)\delta_i; \ \delta_i = \begin{cases} 1, \\ 0, \end{cases} \ i = \overline{1,n}; \ j = \overline{1,m}.$$

The presence of purpose function $\varphi(\alpha)$ and achievement of its maximum $\text{extr}\varphi(\alpha)$ is the necessary condition of the optimal unification. The purpose function $\varphi(\alpha)$ in common case is a limited discrete function permitted values of which form the finite multitude $Z = \{\varphi_i(\alpha)\}$, $i \in \overline{[1,n]}$. One of these multitude elements would turn out extremum (max or min).

In particular cases the purposed function $\varphi(\alpha)$ is often understood as goods quality, i.e. agreement of the properties to satisfy the needs according to the purpose.

The unification effectiveness as a degree of the electronic modules nomenclature organization is determined by proportion:

$$\Delta H(S) = H_0(S) - H_1(S),$$

$$\Delta H(L) = H_0(L) - H_1(L).$$

The RES entropy value $H_0(S)$ before the unification can be accepted as a threshold meaning

$$H_0(S) = H(S_{\max}) = \log_2 d.$$

At the number modules typesizes in module system d_1 and system family d_2 unification effectiveness is:

$$0 \le \Delta H(S) \le \log_2 d_1;$$

$$0 \le \Delta H(L) \le \log_2 d_2;$$

Maximum unification effectiveness $\Delta H(S) = \log_2 d_1$; $\Delta H(L) = \log_2 d_2$ is achieved when the system or system family keeps only one typesize modules. In this case $H_1(S) = 0$, $H_2(L) = 0$, i.e. the whole system regulation appears.

For above-mentioned television example for the threshold meaning entropy before unification can be taken according to table 1: $H_0(s) = H_1(S_{\max}) = \log_2 d = \log_2 10 \approx 3{,}33$. After modification (table 2): $\log_2 6 \approx 2{,}5$, i.e. entropy is reduced by 1,332 times.

Inherent to entropy unmeaning causes retribution of modules.

The given examples present the simplest illustration of the estimation of the RES unification. For the engineering practice next generalizations should be added.

1. Module principle of creating REA is already widely used in industry to shorten the time of assimilation of new electronic devices, hence the definite experience in this sphere is accumulated.
2. While projecting the row of specific tasks appears such as compatibility of the electronic modules. Moduleness and compatibility as mutually connected and mutually stipulated tendency of the development assist successful decision of the questions of different components effectiveness in RES; increase of system adaptability to the kind of the solving tasks; reducing terms of the development, adjusting, modernization and restoration of RES capacity for work.

3. Variety of the REA module equipment can be represented as module entropy and calculated according to Shannon's formula. Moreover, the introduction of the special coefficient allows taking into account the module complexity that would make the REA unification process more effective.

References

1. Verhopjatnitsky P.D., Latinsky V.S. Reference book for radio-electronic equipment constructing. In Russian. — L.: Shipbuilding, 1983. — 232 p.

2. Robert R. Stoll. Oberlin College. Sets, Logic and Axiomatic Theories. In Russian: Множества, Логика. Аксиоматические теории. Пер. с англ. Ю.А. Гастева и И.Х. Шмаина. Под ред. Ю.А. Шихановича. — М.: Просвещение, 1968. — 232 с.

3. Record ВЦ-311, Record ВЦ-311Д. Instruction for repair.— Voronezh: RIO Uprpoligraphizdat. Printing-office "Communa", 1982.

К информационному обеспечению модульного проектирования радиоэлектронных средств

А.А. Зотов[1], В.А. Зотов[2]

Кафедра "Конструирование радиоэлектронных и микропроцессорных систем", ТГТУ (1);
13-й государственный научно-исследовательский институт Министерства обороны РФ (2)

Ключевые слова и фразы: модульная радиоэлектронная система; модульная унификация; совместимость модулей; типоразмер модулей; электронный модуль; энтропия модульной системы.

Аннотация: В практике проектирования радиоэлектронных средств (**РЭС**) все более широкое применение находят модули. На базе формализованных представлений моудльных систем в статье рассматривается энтропийный принцип модульного проектирования, применение которого сокращает сроки разработки, отладки, модернизации и восстановления работоспособности РЭС.

Zur informativen Versorgung der modularen Projektierung der radioelektronischen Mittel

Zusammenfassung: In der Praxis der Projektierung der radioelektronischen Mittel finden die Moduln die immer mehr breite Anwendung. Auf Grund der Formellvorstellungen der modularen Systeme wird es im Artikel das Entropieprinzip der modularen Projektierung betrachtet, dessen Anwendung die Dauer der Erarbeitung, der Austesten, der Modernisierungen und der Wiederherstellung der Arbeitsfähigkeit der radioelektronischen Mittel verringert.

Sur l'assurance modulaire de la projection des moyens radioélectroniques

Résumé: La pratique de la projection des moyens radioélectroniques (**MRE**) prévoit un large emploi des modules. A la base des représentations formalisées des systèmes modulaires on examine dans cet article le principe d'entropie pour la projection modulaire, l'application duquel réduit les délais de l'élaboration, du mise au point, de la modernisation et de la restauration de la capacité de travail des (**MRE**).