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PROBLEM-ORIENTED APPROACH TO SOLVING THE PROBLEMS OF ELECTRONIC EQUIPMENT DESIGN IN CAD

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New approach to electronic equipment design based on ranking by special characteristics and further optimization of printed wire length has been suggested. The example of research works carried out applying the given approach was presented.

One of tendencies of electronics development consists in expansion of its application domains that is a great variety of electronics designed for various fields of science and technology is observed. Electronics is complicated, requirements to its reliability are increased, more indicated, intelligent rich problems increasing efficiency and quality of user operation are solved with its help. Another tendency is the increase of capabilities of computer-aided design (CAD) for end-to-end design at a higher level [1].

In this connection new problems occur both in schematic and engineering design as well as at their junction.

Among the design problems the following ones should be singled out:

- absence of methodical recommendations taking into account modern design styles and occurring problems;
- insufficient accounting of all important requirements for the device and specific features of its elements in connection with limited capacities of their processing in CAD;
- weak information supply of technicians in the questions of using automatic, interactive and compound modes at wide unused capacities of CAD;
- complexity of forming placement and routing strategies at the variety of adjustable parameters (for, example tracer SPECCTRA has 169 adjustable parameters);
- data exchange rules are not sufficiently formalized between circuit engineers and designers as well as between other technicians;
- complicity of solving problems of design optimization in CAD as it is multiparametric, weak-formalized tasks of labyrinth type requiring high-level skills both in object domain and information technologies;
- increase of requirements for topology of printed conductors due to significant increase of digital circuit speed.

The listed problems indicate the fact that the new approach is required for electronics design in modern CAD and on modern level. It gives information to technicians required for reducing design period and increasing quality of the product. As it was mentioned in [1] information technologies of design possess not only great facilities but new demands as well for optimal use of these facilities.

Information technologies requirements consist in the fact that limited capacities of design process formalization and accounting all factors influencing the design decisions in comparison with decision variability accepted by man intelligence require special initial information. This information should not be a set of elementary recommendations but a formalized and arranged instrument which combines the main modern requirements to the equipment, criteria of selecting qualitative decisions and capacities of modern CAD within end-to-end strategy of device design.

To formalize and systemize the whole information required for design the object-oriented approach may be applied. All parts of the device whether it is a printed circuit board (PCB) or electronic component are the objects with specified parameters. A set of object properties required for design is limited by a type of applied component, demands to the device, capacities of the applied CAD etc. Combination of these properties by a special method with demands to the device, criteria of engineering solution selection and CAD capacities gives necessary information for generating end-to-end design strategy.

The term «object-oriented information» can be applied to this information as it describes properties of device objects and their combinations in the form required for making and implementing design decision. However, considering established notions on the combination «object-oriented» itself another term – problem-oriented information (POI) is suggested to be applied. This term reflects as well the matter of the aforesaid information but from the point of view of its direct function.

POI definition may be determined as: information developed on the basis of object-oriented approach the structure and composition of which is determined by the solved problem.

The approach to design based on formation of end-to-end design philosophy from problem-oriented information is called problem-oriented approach.

The main goal of this approach application is maximum possible, qualitative, conscious use of CAD features and, first of all, just automated modes which have a majority of adjustable parameters. At such approach the main attention of the developers is given to making qualitative design decisions but not to the multiple homogeneous operations typical for operation in interactive mode.

To implement designing on such high level it is necessary firstly to search, systematize, structure and classify such initial information as well as technique of its formation and application.

Then the descriptions and results of research works devoted to search and optimization of applying problem-oriented parameters at designing are given. The investigations wee carried out in the following directions: optimization of PCB construction applying POI and optimization of PCB quality control by simulating with POI.

1. Optimization of design stages in P-CAD medium saving and increasing quality of PCB tracing

The aim of the investigations consists in:

- search and classification of POI;
- determination of possibility of applying PCB automatic arrangement and tracing using POI without loss of signal transfer quality and other characteristics of the devices.

These problems solution was required by the results of studying and analyzing electronics design problems of in CAD infomedia in Russia.

The results of analysis showed that PCB is mainly constructed in interactive mode that is confirmed in [6]. Engineers do not trust to automatic mode of placement and routing owing to uncertainty of quality assurance at signal transfer, on the one hand, and on the other hand, they do not possess the techniques of solving polyvalent tasks for selecting parameter optimal combinations for PCB arrangement and tracing policy. The developers of tracer SPECCTRA do not give any references on selecting parameters of PCB arrangement and tracing policy they just propose an averaged variant of the policy which does not take into account the peculiarities of different chart variants. These are the reason why it is necessary to carry out investigations with a great number of computer experiments for solving the above mentioned problems.

Performing the works in searching for problem-oriented information the charts were for the first time classified by design, functional and design-functional complexity (Fig. 1). To determine maximal length of high-frequency circuits and its accounting at design two problem-oriented parameters were applied: functional complexity (circuit ranking depending on signal switching frequency in them) and design-functional complexity (accounting of maximum allowed length of conductor for the given frequency). Use of these criteria implies device circuit division into low-frequency and high-frequency and application of various design rules for each group. Such approach is explained by the fact that in low-frequency circuits signals do not lose clearness and real circuit operation coincides perfectly with logic circuit whereas in high-speed circuits signals are distorted almost beyond recognition [4].

In the paper the technique of applying two above mentioned parameters of POI at PCB construction is suggested. It includes the following stages:

I. Circuit ranking according to the maximal frequencies of signal switching in them and determining maximum allowed length.

According to the information about signal switching frequencies in conductors the developer divides circuits into two groups: high-frequency (the length should be strictly limited) and low-frequency. Maximum allowed value of signal switching frequency in the circuit is determined by two groups of parameters: maximum possible value of frequency at the output of signal source $f_{И макс}$ and maximum possible values of signal switching frequency at receiver inputs $f_{П1\ макс}..f_{Пn\ макс}$. Values $f_{И\ макс}$ and $f_{П1\ макс}..f_{Пn\ макс}$ may be found out of certificates for proper elements. This information may be indicated both explicitly (immediate frequency value) and in the form of values of signal propagation delays in the element which may help at frequency value computation.

Maximum allowed frequency of signal switching in the circuit equals to a minimum of $f_{И макс}$ and $f_{П1\ макс}..f_{Пn\ макс}$. According to this frequency value the circuits are ranked that is divided into high-frequency and low-frequency ones.

The results of ranking as well as found values of maximum allowed frequency for each conductor are proposed to be entered into the table (Table 1).

Then it is necessary to calculate values of maximum allowed length for conductors the length of which should be limited and include these data into the table.

It may be done both manually calculating values by the formula (*) and applying the program MaxLength developed by the author which allows computing rapidly and saving results in the file in the form convenient for use:

$$l_{макс} = t_{ф} v / 4, \qquad (*)$$

where $t_ф$ is the front length, v=2·10⁹ m/s is the rate of signal propagation in the line at medium dielectric constant =2,25 [7].

II. Limitation of wire length in CAD.

According to the results of computations (Table 1) the developer places a limitation on conductor length in P-CAD PCB. To perform this operation the algorithm and instruction for user were developed [8].

Table 1. *The results of ranking circuits and computation of acceptable conductor length*

Net	Connection	Termination style	Frequency, MHz	Length, mm
A2	DD2-6	Input	–	54
	DD3-6	Output	9	
A4	1-A3	Output	7,3	68
	DD2-8	Input	–	

III. Arrangement and tracing of the card taking into account the obtained limitations for high-frequency net length.

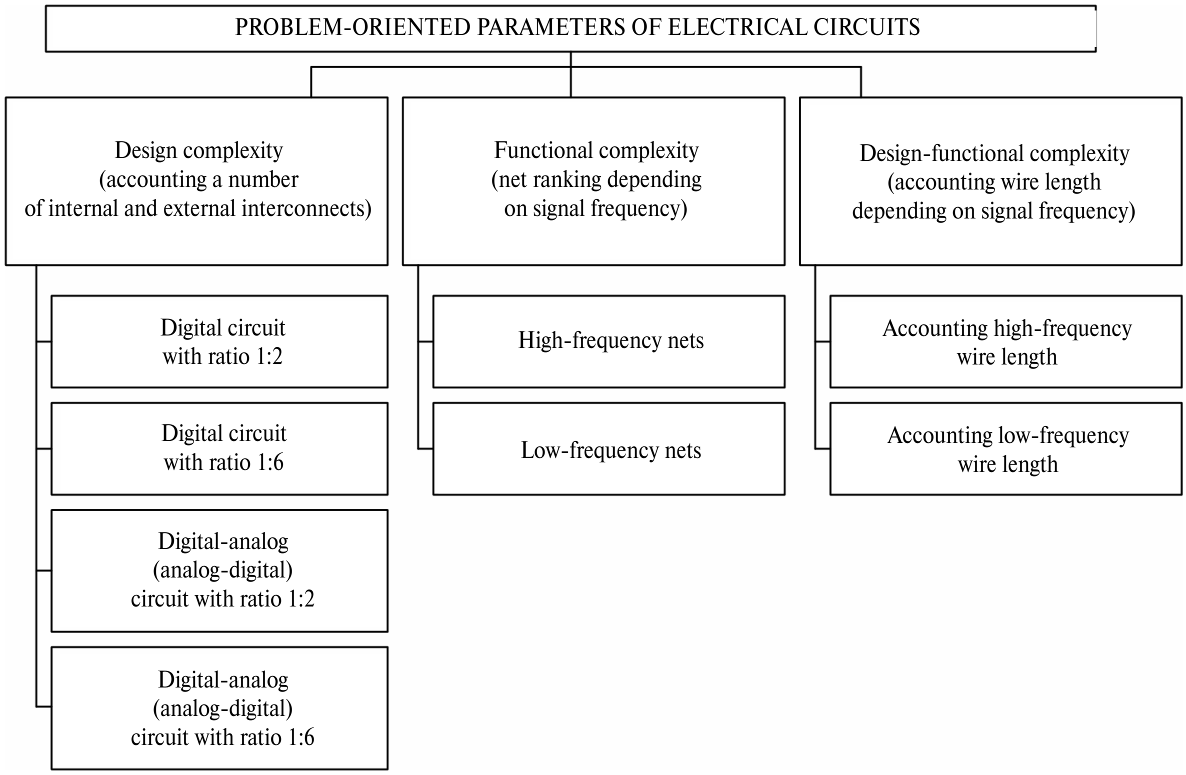


Fig. 1. *Classification of problem-oriented parameters of electrical circuits*

To optimize the placement and tracing the experiments on PCB construction for selected circuit diagram were carried out. Placement and tracing of the card were performed in three variants: applying interactive, automatic and mixed modes (Fig. 2).

After tracing in three given modes its results were compared by several criteria (Fig. 3). On the given bar charts column № 1 refers to interactive mode, column № 2 refers to automatic one and column № 3 – to the mixed mode.

The analysis of the experiment results allows making the following conclusions:

1. Mixed mode of design is the most efficient due to the minimum of interactive processing and application of automatic tracing.
2. Quality of tracing performed with POI application is the most defined as:
   - reliability of circuit operation is supported owing to limitation of maximal length of high-frequency circuits at interactive tracing;
   - tracing variant obtained in automatic mode is optimized as total wire length and a number of via-holes are minimized due to optimization of POI application policy (circuit classification by design complexity).

As a result, increasing productivity of design engineer approaches significantly to CAD facilities at considerable decrease of his labor tension, reduction of PCB design time and support of reliability of circuit operation.

2. Investigation of PCB design quality by electromagnetic compatibility in P-CAD 2002

CAD facilities by simulation of digital signal origin by printed conductor subject to the possible distortions were studied in the paper. Having analyzed the facilities of simulation the technique of designing investigation process of PCB quality subject to occurring disturbances was developed.

It became clear while working on the technique that signal quality may be checked up by simulation for all device circuits with numerous combinations of signal parameters in the considered and neighbor circuits. However, such redundancy is not appropriate because of the following reasons:

- high time expenditures for simulation;
- labor of results analysis because of their large amount;
- ambiguity at developing references for disturbance decrease (it is not clear exactly what measurers should be assumed for decreasing disturbances in a concrete circuit).

Therefore, it was suggested to divide nets into groups and each circuit ranking. In this case classification by functional complexity was used (Fig. 1). Ranking was carried out by the following criteria:

- importance of the performed function;
- frequency of signal switching in a net;
- noise-immunity of the elements connected to a net.

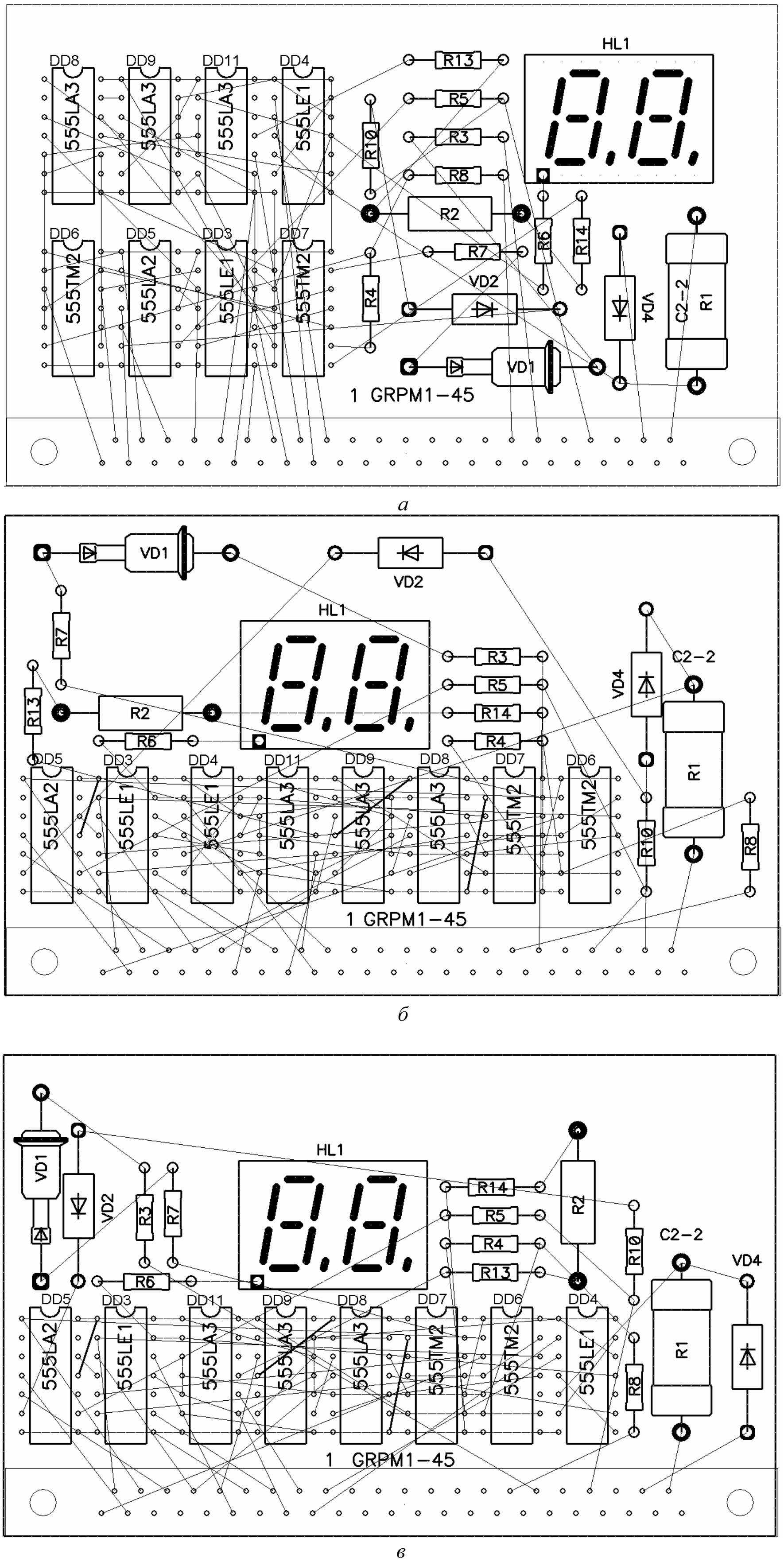
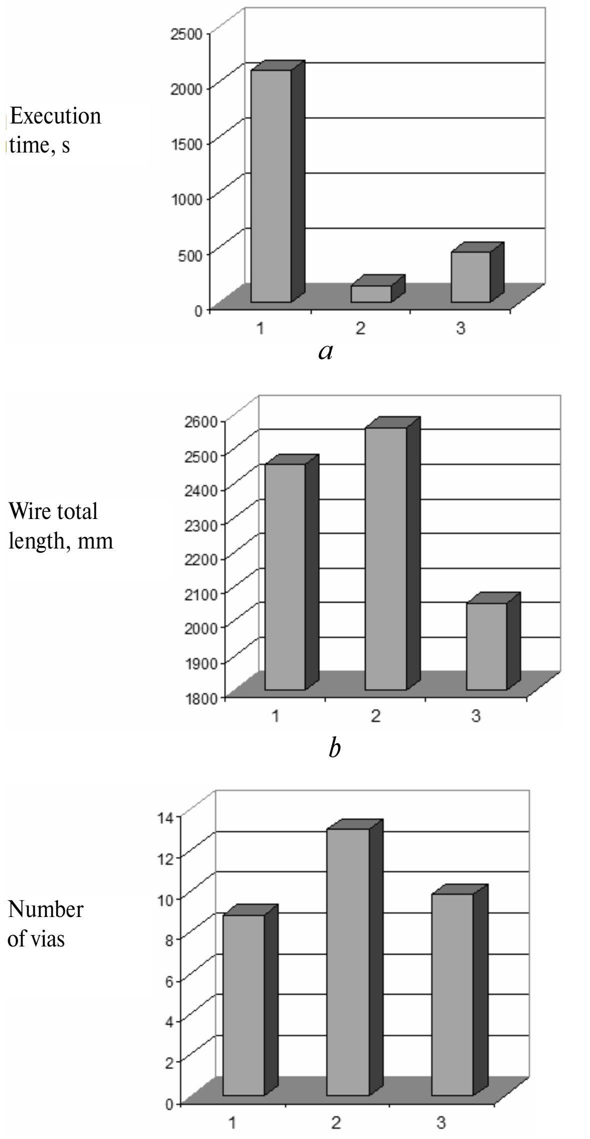


Fig. 2. *Variants of placement obtained in different modes: a) interactive, b) automatic and (c) mixed*



c

Fig. 3. *Comparison of tracing results by criteria: (a) execution time; (b) total length of conductors and (c) number of via-holes*

Nets may be divided by the performed function into groups according to possible common consequences which are the result of signal distortion in it. For example, failure in timing signals or control nets by possible consequences is worth than a simple data distortion. Importance of nets inside of one group may be different as well.

Noise-immunity of an element is defined by element reaction on voltage surge on its input. High-speed element may react on voltage pulse caused by a crosstalk (Fig. 5, *b*) whereas a low-frequency element does not react on this pulse [2, 3]. Therefore, high-frequency circuits and elements are more vulnerable than low-frequency ones therefore, they are more important.

Net ranking allows determining how detailed signal distortion should be studied in each net, how many tests should be carried out, how many different variants of adjustments for simulation parameters should be used.

Quality is suggested to be studied in sequence reflected in Fig. 4.

Nets are ranked on the stage of gathering preliminary information. Within this paper ranking was carried out in two stages:

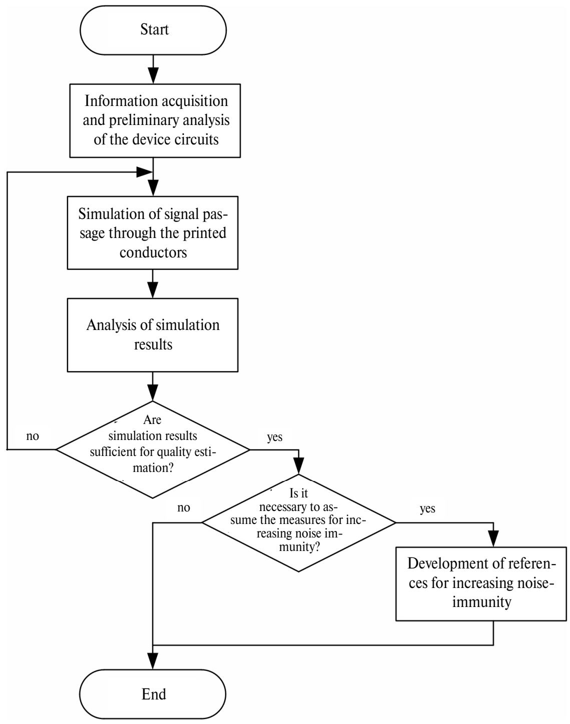


Fig. 4. *Algorithm of quality research of printed circuit board by simulation*

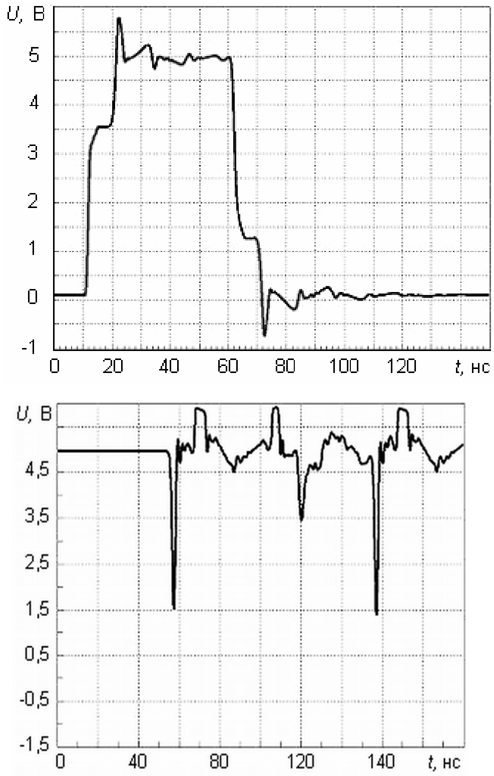
1. Division of nets into groups by importance and frequency of signal switching ranking each group.
2. Each net ranking according to the information on component noise immunity.

The example of net ranking is given in Table 2. In this case nets were combined into three groups: sync, control and information nets.

Table 2. *Table of circuit, element and rank characteristics*

Net	Notion of SSI	SSI part type	U_{Lmin}, B	U_{Lmax}, B	U_{Hmin}, B	U_{Hmax}, B	Rank
Sync nets							
CLK0	U1, U6	SN74ACT2440FN	–1	0,8	2	7	102
OSC	U2	SN74ACT2440FN	–1	0,8	2	7	101
	U4	TLC34058-80GA	–0,8	0,7	2	6,8	
Control nets							
HRD	U2	SN74ACT2440FN	–1	0,8	2	7	202
	U4	TLC34058-80GA	–0,8	0,7	2	6,8	
AEN	U2	SN74ACT2440FN	–1	0,8	2	7	201

Each net rank is composed of two components. High-order digit is the group rank and the rest digits is the circuit rank inside this group. Net and group ranks are numbered in ascending order by decreasing quality and noise immunity.



a

b

Fig. 5. *Variations of signal distortions in conductors: a) signal edge distortion because of reflection effect; b) constant signal distortion because of crosstalks*

For example, rank 102 is given to net CLK0. It means that the group in which there is this net is the most important and the net itself is the second by importance among of its group.

Then it is necessary to determine quantity of tests for each net and medium adjustments for each test subject to net rank. This information should be introduced into test table that allows simulating as soon as possible.

If quality research reveals signal distortions in long unmatched wires (Fig. 5, *a*) or possible signal distortions due to crosstalks (Fig. 5, *b*) then analyzing simulation results and generating decisions on increasing device noise immunity the circuit rank determines gravity of deviations in signal quality and importance of measures to be assumed for supporting this signal integrity.

The results of researches on electronics design optimization in CAD showed that intelligent design systems operate more efficiently if they get intelligent structured information taking into account possibilities and peculiarities of used system as input parameters and adjustments. At such approach the design process itself changes qualitatively as the main attention is given to analyzing device features, developing and implementing end-to-end design philosophy but not to its numerous homogeneous operations typical for design in interactive mode.

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