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# A PERSONAL CAD SYSTEM FOR REMA MICROPROCESSOR PRINTED CIRCUIT BOARDS*

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1. Introduction. The application in autonomous devices and automatic systems of the collection, processing, and display of medico-biological information from built-in microprocessor modules [2] based on corresponding printed circuit boards (PCB) has made it necessary to create CADS (computer-aided design system) and the automated production of PCB for REMA. The first version of a two-level REMA PCB CADS based on standard domestic hardware of the COM and AWP (automated work place) ES (expert sytem) type of PCB designer is described in [6] and was tested at the experimental factory of the All-Union Scientific Research Institute of Medical Instrumentation (OZ VNIIMP).

At the same time the REMA PCB was unitized and standardized, which was taken into account in the corresponding CADS DB [1].

In Western Europe the CADS market, according to Dataquest Inc. (USA), by the end of 1988 had reached a volume of the order of 2 million dollars. In the next four years, in the opinion of the major producer of CADS programs in Western Europe, the "Robocom" corporation, approximately one million designers will replace their drawing boards with personal CADS based on microcomputers. By 1990 the proportion of CADS used in the design of machine parts will decline from 59% to 46%, while the proportion of CADS used in the electronic and electrical-engineering industries will increase from 22 to 33% [4]. A catalog of the most widely used CADS and a description of their characteristics may be found in the literature [4, 7, 10, 12-15].

In recent years in domestic and foreign PCB CADS development PC have found wide application [7, 10, 12-15] together with artificial-intelligence systems in the form of ES with the corresponding APP and knowledge base [5, 8, 11]. The creation of problem-oriented personal CADS based on flexible intellectual work stations for the designer with the stations combined into a single local network is one of the promising new directions in which personal CADS are developing. Intellectual CADS take on special significance in the development and design of a new type of medical apparatus - medical ES realized as low-definition controllers [16] based on microprocessor PCB in the form of built-in modules (for example, for the programmed control by intellectual-accessory apparatus of the restoration of lost functions: artificial ventilation of the lungs [3], and artificial kidney to produce dialyzate [9] et al.).

The development of intellectual personal ADS (according to the evaluations given in [11]) take from 200 to 250 man-years. From an organizational point of view such a model of an intellectual CADS may be developed in not less than seven years [11] and requires the close coperation of specialists in various fields.

One of the possible directions in which the automation of REMA PCB might move is the development of man-machine systems combining the principles of AWP-based circuit design (realized using PC of the PC XT/AT type), the automation of routine preparation of industrial-design documentation (IDD), and the outputing of information carriers for external production equipment and tools with NPC (numerical programmed control).

*Special abbrevations used are listed at the end of this article.

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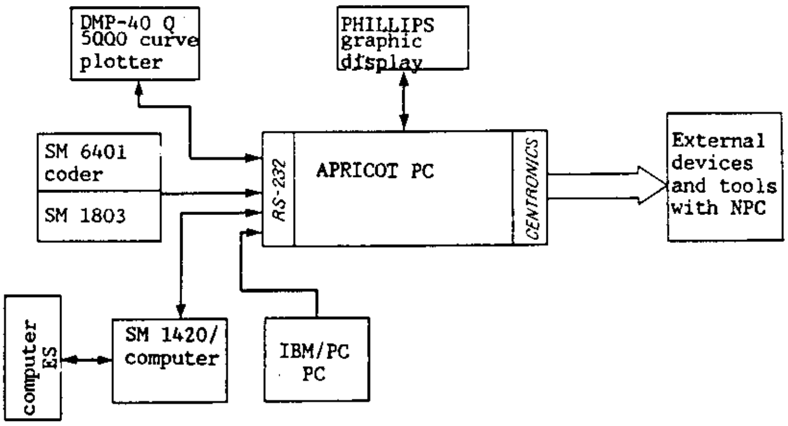


Fig. 1. Structural block diagram of the CADS/SNAKE hardware.

Current CADS based on AWP and using PC of the IBM PC XT/AT or EC 1840/1841 type are used in one or another form for the design of PCB [10, 12-15]. Many APP have been developed for such CADS. Thus, for PC of the PC XT/AT type there are the PCDESIGN, smAPIWORK, and P-CAD packages [15], while for a work station of the DASH-2 Workstation type the DASOFT DESIGN SYSTEMS [13] package and others have been developed [12]. For domestic CADS of the PRAM 5.3, ARM-PLAT, and GRAD type there exist sufficiently developed programs with appropriate APP.

At the present time there are many attempts to apply foreign PC in domestic CADS in order to improve the characteristics both their hardware and their software. In many cases, however, significant difficulties arise as a result of the lack of software and hardware interfacing with existing domestic input/output devices.

The present article describes the hardware and software of a personal CADS as a man-machine system instanced by the structure of the CADS/SNAKE hardware and software interface with a base PC of the APRICOT XI type and a QUEST DRACON graphic system with a dialog editing mode.

This modification of the personal CADS is a second version of the CADS described in [6] and is a system for the graphic design and manufacture of PCB masks, information carriers for tools with NPC, and external production equipment. In order to realize the circuit design process in a CADS as a man-machine system the hardware and software include a graph and text information language (GTIL) and a corresponding file converter program, which permits use of the CADS with domestic and foreign CADS.

Let us examine certain features of the methods and hardware and software of PCB design in a CADS with an APRICOT type base PC.

2. CADS/SNAKE Hardware and Software. CADS/SNAKE, which is oriented toward mechanical-engineering graphic design and the outputing of the corresponding graphic documentation, for a number of reasons (primarily the low resolution of the graphic system) have not met their requirements fully. A limited inventory of the capacities of the system has posed the problem of increasing the potential of the CADS by reorienting it to other tasks, in particular the design of PCB.

The specification of the design of PCB proposes both full (or partial) automation of the layout process and a stage of editing and outputing of IDD. There are certain factors which in a number of cases do not permit use of full automation of the design process. Thus, the final product of an automated design process as a rule has a larger surplus of interlayer transition elements, conductor bends etc. than the results of an experienced designer's work. This is one of the basic factors in the creation of the corresponding ES in intellectual REMA PCB CADS.

It is necessary also to take into account the fact that modern saturated single-layer microprocessor boards are still difficult to subject to 100% layout.

Therefore one of the stages of the modernization of CADS/SNAKE was the development of a semiautomated mode for the preparation and outputing of IDD. In connection with the above-mentioned factors, let us briefly consider additional features of the changes in CADS/SNAKE.

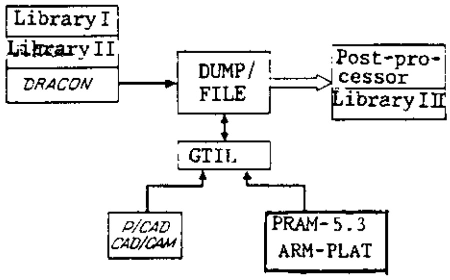


Fig. 2. Structural block diagram of the CADS/SNAKE programming.

2.1 Hardware Modernization. Designing directly in the screen mode is a laborious and frequently prolonged process. It was therefore necessary to solve the problem of including in the complex a device for coding graphic information. In order to realize the process of copying a hand-drawn PCB, a domestic coder of the SM 6401 type with an intellect based on an SM 1803-type computer through an RS-232 interface channel is connected directly to an APRICOT-type PC (Fig. 1).

The coding data are transferred by a single unit (or to a screen in the direct-output mode) over the link for further graphic processing. The CADS/SNAKE output unit is organized on the basis of a perforated-tape station of the SM 6204 type through a CENTRONICS port.* Taking into account the fact that perforated type is an unreliable information carrier, this channel is doubled by a direct connection between the coordinatograph to an SM 1420 type computer or to the base PC. The results of the projection are conveyed by means of a magnetic carrier. This constructive solution is expedient also in that it gives the possibility of operative introduction of editorial changes into the mask.

2.2. Program Structure. The program section of CADS/SNAKE is shown in Fig. 2 and is constructed as follows. The base graphic system is DRACON 1.6C, in which one of the input/-output parameters is a so-called DUMP/FILE file, which is a description of graphic units in ASCII codes in a QUEST format. In order to expand the forms of system usage a domestic GTIL format was included in the program section. This makes possible the combined use of domestic CADS such as PRAM 5.3, ARM-PLAT, GRAD, as well as foreign CADS of the CAD/CAM or P-CAD type.

Thus a closed CADS structure is created with the possibility of connecting to it CADS without graphic facilities (of the PRAM 5.3 type) as well as CADS without outputs to domestic technological equipment (of the CAD/CAM or P-CAD type). This question is described in greater detail in Section 2.4.

2.3. Structure of the CADS/SNAKE Library. The structure of the CADS/SNAKE libraries is based on the functional-application principle:
- a DRACON base graphic library in Tsokolev form;
- an alternative DRACON graphic library in assembly units; and
- a library of coordinate units representing the "unpacking" of a complex element.

The base graphic library is constructed on the basis of single library units (KP) into complex forms (microcircuits, connectors, etc.). The alternative library is constructed in such a way that the position number of an assembly unit coincides with the position number of the base library of this element. This structure permits operative transition from a topology diagram to an assembly diagram through reassignment of the list status library, which is expedient in the creation of design documentation. The library of coordinate units is the basis of the postprocessor portion of CADS/SNAKE and contains information in the form of the coordinate units of the complex library elements relative to the base point.

2.4. The File Converter Program to Link the REMA PCB CADS to the SM 1420 and CAD/CAM.† The combined use of two systems - a CADS based on a computer of the SM 1420 type and a CADS of the CAD/CAM type built on a PC of the IBM PCXT/AT type - permits taking advantage of the

*This is associated with the fact that until now technological equipment primarily operates via a perforated-tape information carrier.

†Developed in collaboration with A. A. Belyakov, M. P. Naumchik, and M. Yu. Levin.

advantages of both systems, making possible the rapid production of experimental and mock-up PCB samples and the machine generation of design documentation and PCB masks.

A significant shortcoming of this approach is the need for laborious inputing of information into each of the systems. Double inputing of information is accomplished by linking the two CADS programs. In this case the inputing and correcting of data is performed in the interactive mode in the CAD/CAM system, while the copying processing the SM 1420-based CADS is eliminated.

Joining the two systems permits automated design. For this it was necessary to find an information transmission method in the SM 1420-based CADS to transmit graphic information in the required format, exhaustively describing the topology and the marking and protective layers of both sides of the PCB being designed. A portion of this task is solved by the file converter program which converts the data format and which is used in the LPKF program package of the CAD/CAM system, into the GTIL format as the language of internal representation of graphic and text information in the SM 1420-based CADS (CADS/SNAKE).

The file converter program is written for PC which are compatible with IBM PC in the PASCAL-Turbo language and occupies a memory volume of about 43 Kbyte. The operating time is from 10 to 20 minutes depending on the saturation of the board being designed.

The program uses as input data files formed during the running through of the COLOR-CAM package and designed for a driver program controlling a six-color curve plotter of the MR 1000 type.

The converter program forms four output text files in GTIL. The information is distributed to the files as follows:

- gaps and contact areas of given shapes and dimensions;
- contour lines of attached elements and grid lines;
- conductors on the element mounting side and on the reverse PCB side.

This distribution provides the necessary initial data, in the absence of redundant information, by combining different files, for the machine production of diagrams and masks of each side of the PCB and also perforated tapes for NPC tools.

This provides 12 contact areas of circular and rectangular shape. The width of the printed conductors and the output data can take on not more than four values. In spite of these limitations the converter program has adequate flexibility, since the dimensions, area shapes, and conductor widths in the output data may be established by the user according to his own judgement from the standard geometrical elements in the library. This operation can be performed when the program is run before the processing of the input data by making changes in the DB.

In this case the DB is a file consisting of a number of records, four of which are reserved for conductors, 12 for contact areas, and one for grid patterns.

If the DB is not located when the program starts, a request for the creation of a new "empty" file is made. If this request is refused the program completes its operations without processing the input data.

The process of running the program may be divided into three stages.

The first stage is a dialog with the user in the menu mode. The name of the input file, the discreteness of the coordinate grid, the dimensions of the board and a number of other parameters are specified. By moving from the menu to the DB, it is possible to introduce changes in a particular board. If desired the changes can be kept by giving the record command, otherwise they will remain in force for one run of the program. By means of the commands in the menu the program can be completed or the second stage of the operation can be performed.

In the second stage necessary information is extracted from the input file, sorted with regard to layer and object (contact area, conductor, or grid line), and allocated in the temporary files. The need for such sorting derives from the characteristics of the GTIL format.

In the third and final stage the temporary files are processed in accordance with the GTIL. The information is relayed to the four output files. The temporary files are erased and their information outputed to the initial menu, where the user may at his discretion either begin working with other input data or complete the running of the program.

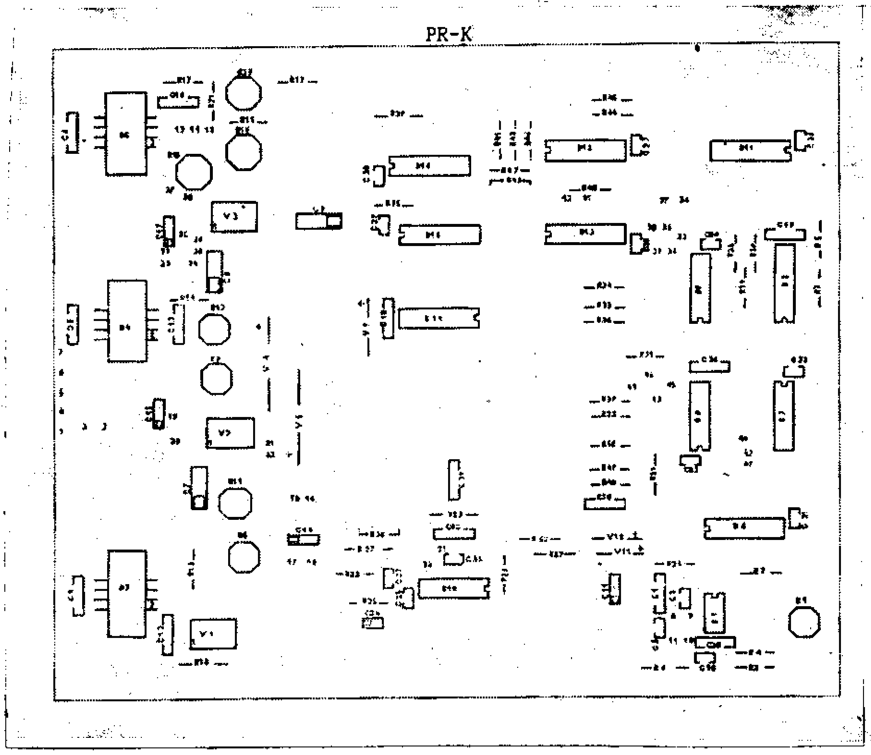


Fig. 3. Example of grid pattern of a PR-K board mask.

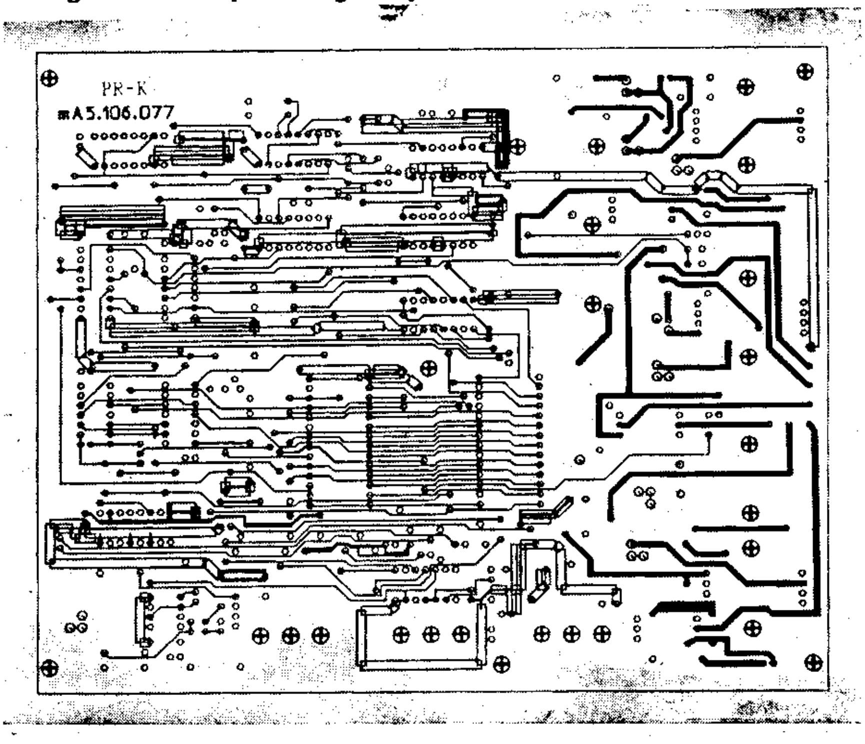


Fig. 4. Example of a PR-K board mask.

Transmission of the data formed by the converter program of the files in CADS/SNAKE proceeds in two stages:

- transcription from diskette to SM computer magnetic tape in PSX format; and
- reformating in DOS.

Data from the IBM PC are transmitted over a series channel (an RS-232C interface) to the SM 1420 (see Fig. 1). The data array in PSX format is converted to DOS format and recorded on magnetic tape. The information may be used in an APP of the GRIF type [6]. This package prepares and outputs IDD on the PCB. If necessary there is the possibility of graphic editing of the data.

Tests and usage of the programming have demonstrated its efficiency and that of the CADS as a whole. Combining the two CADS resulted in an increase in quality and a shortening of processing times.

3. Example. A PR-K copier-programmer was designed to copy information recorded in a PROM (programmable read-only memory) of the K557RF2, RF5, or RF4 type. The board was designed at an AWP with the aid of a CADS of the CAD/CAM type. The IDD (Figs. 3 and 4) was outputed using CADS/SNAKE and a converter program.

Conclusion. Approbation of the programs and use of the CADS at the OZ VNIIMP permit the following conclusions to be drawn.

1. A personal CADS for graphic design and the preparation of PCB masks and information carriers for external industrial equipment and tools with NPC has been developed.

2. The CADS is realized as a man-machine system and operates in an automated or a semi-automated mode.

3. The GTIL language and the converter program included in the hardware-software system allow flexible use of the CADS with domestic and foreign CADS.

4. The CADS/SNAKE hardware-software interface with the base PC and domestic industrial equipment raises the quality of design and outputed IDD, decreases design time, and increases the efficiency of industrial equipment.

## LIST OF SPECIAL ABBREVIATIONS USED IN THE JOURNAL "MEDITSINSKAYA TEKHNIKA" TO DESCRIBE COMPUTERIZED RADIOELECTRONIC MEDICAL APPARATUS

| | |
|---|---|
| AC | analog computer |
| PAM | pulse-amplitude modulation |
| ALD | arithmetic-logic device |
| AM | amplitude modulation |
| AWP | automated work place |
| ACS | automated control system |
| APCS | automated production control system |
| AIPCS | automated industrial process control system |
| AFC | amplitude-frequency characteristic |
| ADC | analog-to-digital converter |
| ANP | alphanumeric printer |
| DB | data base |
| BM | buffer memory |
| LSI | large-scale integration |
| FFT | fast Fourier transform |
| VAC | volt-ampere characteristic |
| VM | video monitor |
| CS | computer system |
| CT | computer technology |
| C | computer [R: "vychis. ustr.," "computing device"] |
| CC | computing center |
| HF | high frequency |
| HIC | hybrid integrated circuit |
| FMS | flexible manufacturing system |
| LCI | liquid-crystal indicator |
| M | memory [R: "memory device"] |
| MCC | measurement computer complex |
| MIS | measurement information system |

| | |
|---|---|
| PCM | pulse code modulation |
| PM | pulse modulation |
| ISS | information search system |
| ISL | information search language |
| RPI | radial parallel interface |
| RSI | radial series interface |
| IM | integral microcircuit |
| CMDS | complementary MDS structure |
| CMOS | complementary MOS structure |
| CMTS | cassette magnetic tape storage |
| SOS | silicon on sapphire |
| DL | delay line |
| MD | magnetic disk |
| MDS | metal dielectric semiconductor |
| MT | magnetic tape |
| MOS | metal oxide semiconductor |
| MP | microprocessor |
| FMDS | floppy-magnetic-disk storage |
| NQC | nondestructive quality control |
| LF | low frequency |
| OM | operative memory |
| SCMC | single-crystal microcontroller |
| SBMC | single-board microcontroller |
| FB | feedback |
| SBC | single-board computer |
| DMA | direct memory access |
| CCD | charge coupling device |
| PM | permanent memory |
| PPM | programmable PM |
| PLM | programmable logic matrix |
| APP | applied-program package |
| PC | personal computer |
| REMA | radioelectronic medical apparatus |
| CADS | computer-assisted design system |
| ARS | automated-regulation system |
| ACS | automated-control system |
| LSI | large-scale integration |
| UHF | ultra-high frequency |
| PD | photodiode |
| MVS | machine vision system |
| DBCS | data base control system |
| SRE | standard replacement element |
| US | ultrasound |
| PD | photodiode |
| PPM | pulse phase modulation |
| FM | phase modulation |
| PFC | phase frequency characteristic |
| PEM | photoelectric multiplier |
| FM | frequency modulation |
| NPC | numerical program control |
| PWM | pulse width modulation |
| DAC | digital-to-analog converter |
| CP | central processor |
| C | computer [R: "EVM," "electronic computing machine"] |
| EBD | electron beam device |
| EBT | electron beam tube |
| EOC | electron-optical converter |
| EPR | electron paramagnetic resonance |
| ES | expert system |
| NQR | nuclear quadrupole resonance |
| NMR | nuclear magnetic resonance |

## LITERATURE CITED


1. E. V. Aleksandrov, Yu. A. Efimov, and S. V. Yl'yanov, Automation of the Design of Printed-Circuit Boards for Electromedical Instruments: (Problems Unitization and Standardization): Abstracts, Information. Moscow (1979). Novosti Med. Tekh., No. 2, 11-15 (1980).
2. V. M. Akhutin, M. G. Markatun, and S. V. Ul'yanov, Med. Tekh., No. 6, 3-8 (1988).
3. O. I. Vasil'eva, I. P. Ionov, P. S. Kantor, and S. V. Ul'yanov, Med. Tekh., No. 1, 17-25 (1989).
4. É. V. Kiseleva, L. S. Morozova, and E. V. Anosova, The Development of CADS/CADS in Western Europe. (Express-Information: Instruments, Automation Methods, and Control Systems/TS-3 Automated Control Systems. No. 12), Moscow (1988).
5. M. I. Koov, M. B. Matskin, and É. Kh. Tyugu, Izv. Akad. Nauk SSSR, Tekh. Kibern., No. 5, 108-118 (1988).
6. V. S. Kukhlevskii, V. A. Min'kov, and S. V. Ul'yanov, Med. Tekh., No. 6, 41-46 (1981).
7. R. Mikushauskas, A. Petkyavichyus, D. Sitsyunene et al., Programmirovanie ÉVM, No. 12, 85-93 (1988).
8. É. Kh. Tyugu (editor), Applied Program Packages in the Priz System [in Russian], Tallin (1988).
9. Z. B. Rakhmanova and S. V. Ul'yanov, Med. Tekh., No. 6, 23-41 (1988).
10. R. Rozenberg, Élektronika, 58, No. 16, 40-43 (1985).
11. B. G. Tamm and É. Kh. Tyugu, Vestn. Akad. Nauk SSSR, No. 5, 39-49 (1988).
12. Sekkei Kikai, Mach. Des., 30, No. 11, Suppl., 10-159 (1986).
13. E. L. Pinto, Special report: Low Cost CAD/CAM Systems (1985).
14. PC Magazine, No. 1, 366-367 (1987).
15. P-CAD Systems. User's Manual Inc. Publ. (1986).
16. M. Togai and H. Watanabe, Inform. Sci., 38, No. 2, 147-163 (1986).