IMPLEMENTATION OF DESIGN AIDS FOR ELECTRONICS IN A NUCLEAR RESEARCH AND DEVELOPMENT ESTABLISHMENT

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ABSTRACT

This paper discusses the implementation of certain computer-aided design (CAD) techniques in an electronics group within a nuclear research and development environment. The approach chosen is described in the light of practical experience gained. Present applications of design aids using an Advanced Design System (ADS) in areas ranging from thick-film artwork to system documentation are given. Further development programs are currently being planned to study these techniques and to apply them to the design of man/machine interfaces that match specific system requirements. ADS is also used to study the interconnection of different specialized systems via a network. These problems are of interest, for example, in designing and optimizing electronic systems for future power reactors.

ABRÉGÉ

Dans cette communication on discute de la mise en pratique de certaines techniques pour faire des plans par ordinateur qui sont utilisées par une groupe d'ingénieurs électroniciens dans un laboratoire de recherche et d'exploitation nucléaire. On décrit la méthode qu'on a choisi après avoir acquis de l'expérience. On décrit aussi les applications actuelles l'aidant des ingénieurs utilisant ce système avancé d'études (Advanced Design System = ADS) dans des travaux allant des configurations de couches épaises à la documentation de systèmes. Actuellement d'autres projets pour l'étude de ces techniques et leur application à la planification des appareils de dialogue entre l'homme et la machine pour des besoins bien définis sont en cours de préparation. On utilise aussi l'ADS pour étudier les liaisons, de divers systèmes spécialisés, en réseau. Ces problèmes se recontrant, par exemple, lors de la planification et de l'optimisation de systèmes électroniques dans les réacteurs nucléaires de l'avenir.

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Introduction

The Electronics Branch at Chalk River Nuclear Laboratories (CRNL) has the responsibility of providing support to the research and development effort related to the nuclear power program. Fields of interest in the Branch range from design and fabrication of thick-film microelectronic circuits to the conception, installation and maintenance of complete turn-key systems.

The incentive for introducing CAD techniques in electronic design procedures was provided initially by two considerations. It has been recognized that interactive graphics can prove valuable in various stages of design sequences*. Furthermore, certain techniques are sufficiently well developed to be practical in solving engineering problems.

Choosing an approach

A first step taken by the Electronics Branch was to study design sequences for electronic units in order to identify areas amenable to CAD techniques. An electronic unit can be either a total system, an instrument or a circuit. Since all electronic units share a similar design morphology[1], a generalized design sequence was formulated and used to help pinpoint specific problems for further analysis. Closer examination of steps in the design sequence revealed that CAD amenable areas involved two different categories of problems: analytical and topological. The demarcation is by no means well-defined. It is convenient to think of analytical aspects as those requiring more mathematical computation. Topological aspects, on the other hand, involve more graphical representation and are concerned with the spatial interrelationships of physical objects according to certain constraints. Based on these guidelines, various design activities in the Electronics Branch were selected and categorized as shown in Table 1.

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* A design sequence can be defined as a series of activities commencing from the initial interpretation of given specifications to the final release of a product that fulfills the requirements.

- CAD
  - ANALYTICAL
    - DEVICE MODELING
    - ANALOG CIRCUIT ANALYSIS AND DESIGN
    - DIGITAL CIRCUIT SIMULATION AND ANALYSIS
    - TEST SEQUENCES
    - SYSTEM SIMULATION
  - TOPOLOGICAL
    - THICK-FILM HYBRID CIRCUIT ARTWORK
    - PRINTED-CIRCUIT BOARD LAYOUT
    - EQUIPMENT FRONT PANEL AND MECHANICAL DESIGN
    - DRAFTING
    - TEXT EDITING
    - DOCUMENTATION

Table 1 – Categories of CAD in Electronics

One requirement in choosing an approach for the implementation of design aids was that it had to offer possibilities of immediate returns, while being sufficiently general to become the starting point of further applications of these techniques in other areas at CRNL. It has been recognized that the design process begins naturally with a graphical description of a new project[2]. The designer can find considerable help in expressing and understanding abstract concepts by using graphical representation. He can also modify his design by manipulating the topological relationships of graphical symbols. In this broad sense, topology has a place right at the inception of any design sequence. Furthermore, in our environment, topological application of CAD promised immediate benefits in areas like printed-circuit board layouts, thick-film hybrid circuit artwork, schematic drawings and design documentation. Thus, commercial suppliers were approached to provide an Advanced Design System (ADS) that met our requirements.

Important considerations in specifying a system configuration were that the man/machine interface should be natural to designers and that a high degree of system availability could be guaranteed. To achieve these goals, a graphics terminal was selected with a highly flexible support package, and the system was required to have 'stand-alone' capability in performing meaningful functions independently of external conditions. The system itself was partitioned into a number of self-sufficient units, each capable of performing certain tasks independently of the others. However, the overall integrity of the system was guaranteed in that all units can be combined when necessary to perform operations that would otherwise be impossible.

The Advanced Design System (ADS)

The system block diagram of ADS* is shown in Fig. 1. The stand-alone CAD Subsystem comprises an Applicon DA 701, an industry-compatible magnetic tape unit, and a Tektronix 4601 Hard Copier. The DA 701 is essentially an interactive graphics station based on a PDP-11 computer. Man/machine graphical interactions are accomplished using a tablet and stylus and a storage tube display. The Hard Copier produces Xerox-like copies of images on the display screen. Output plot files, for driving the plotting equipment in the off-line mode, are generated on the magnetic tape unit. On-line plotting, while work is concurrently proceeding on the CAD Subsystem, is also provided in the multiplex background/foreground mode of operation.

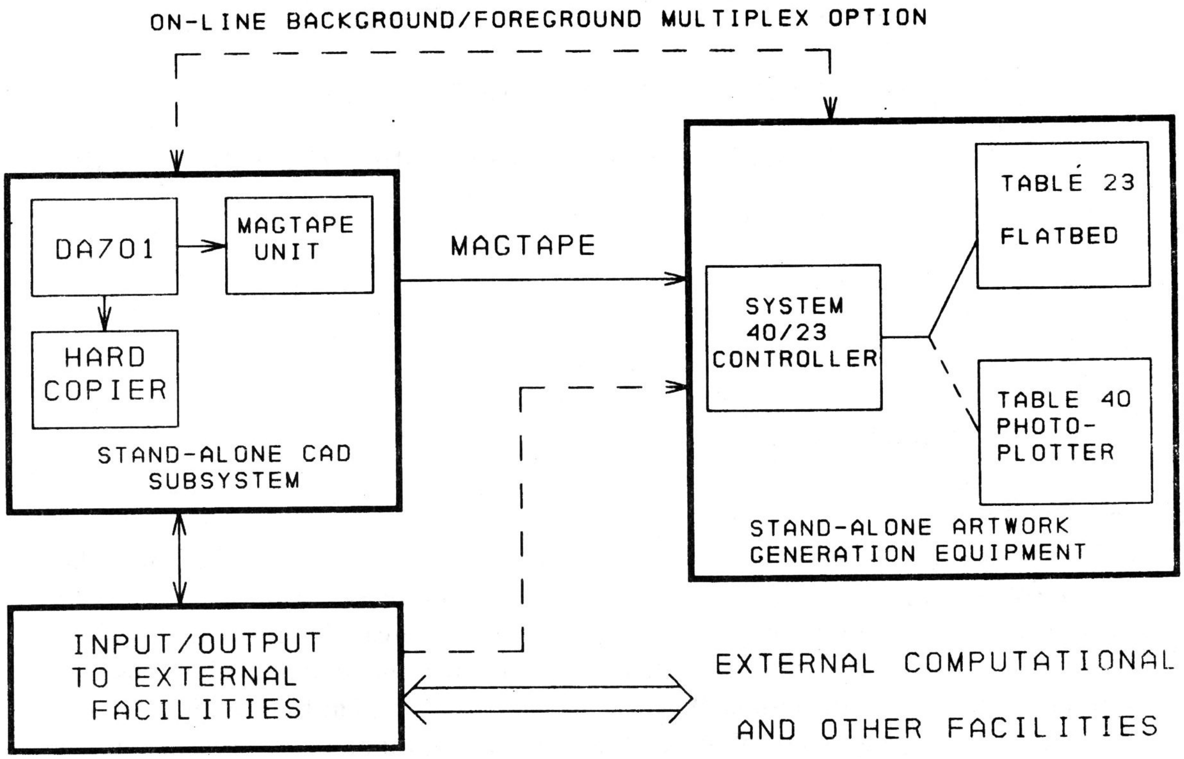

Fig. 1 – Block Diagram of ADS

The stand-alone Artwork Generation Equipment consists of a System 40/23 Controller, a Table 23 Flatbed and a Table 40 Photoplotter, all manufactured by Gerber Scientific Inc. A single controller is used to drive either the Table 23 or the Table 40. This configuration eliminates the need for a second controller at the expense of reducing the maximum plotting speed of the Table 23 from 600 ipm to 300 ipm.

The block "Input/Output to External Facilities" represents a "port" for ADS to communicate with the outside world. ADS is a specialized tool designed to solve a class of topological problems. However, it can become more useful as a design tool if it has access to some external facilities that are more suited to handle analytical aspects of CAD. Even though external communication has not been established yet, it was conceived from the outset as an integral part of ADS.

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* ADS was supplied by Applicon Inc. according to AECL specifications

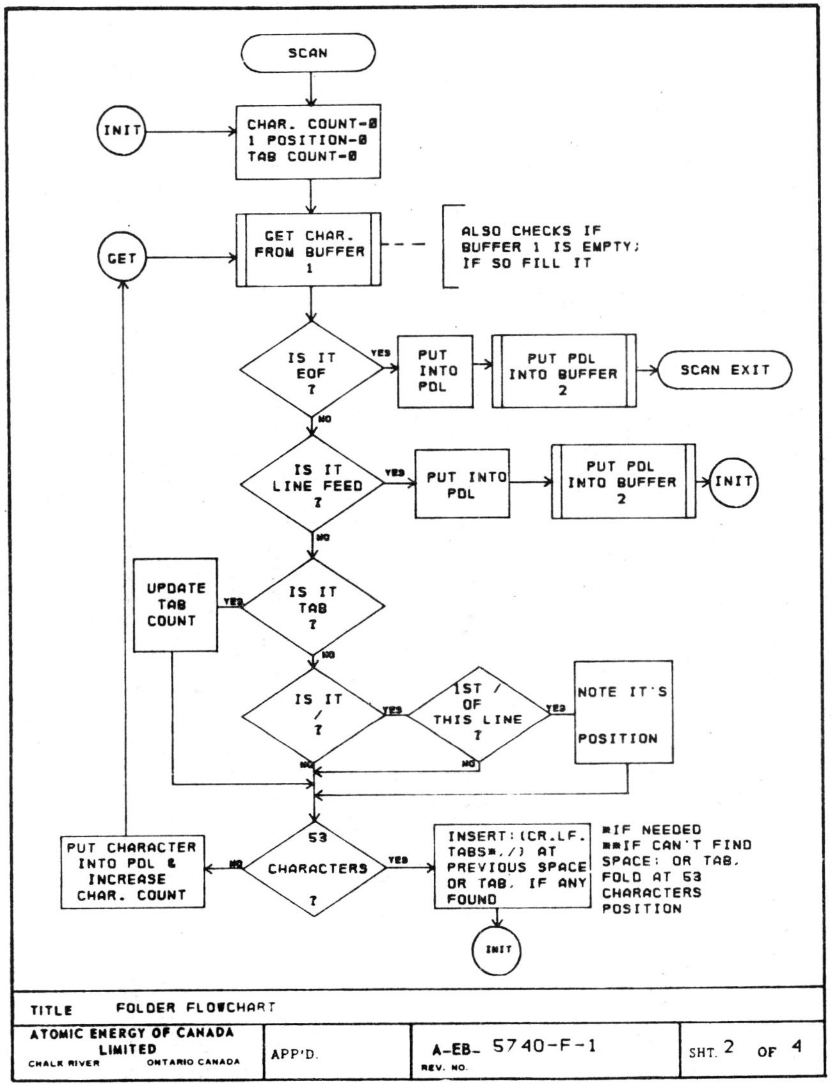
Present Applications

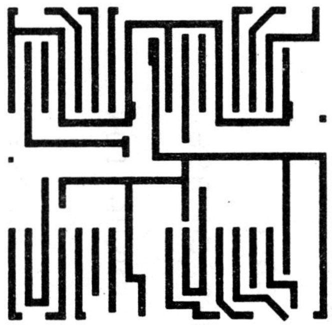
ADS was delivered in May 1972 and has since been successfully integrated into the design activities of the Electronics Branch. The integration process has been achieved by following three interdependent programs: the education, the operation and the development programs (see Table 2).

- ADS
  - EDUCATION
    - USER COURSE
    - DESIGNER COURSE
    - PROGRAMMER COURSE
  - OPERATION
    - ARTWORK GENERATION SERVICES
    - CONTINUING SUPPORT TO USERS
    - MAINTENANCE AND TROUBLE SHOOTING
  - DEVELOPMENT
    - IMPROVEMENT OF DATA STRUCTURE
    - INTERCONNECTION TO BLDG. 600 COMMUNICATION RING
    - MAN/MACHINE INTERFACE PROBLEMS

Table 2 – Implementation of ADS

ADS was conceived as a tool for designers rather than as a facility accessible only through the services of operators. A comprehensive education program was therefore organized and implemented. User manuals were written and courses were given. The manuals reflect the specific characteristics of ADS and the special needs of CRNL. Eighteen users have been trained. After attending a one-day lecture and using the ADS for about 4 hours performing a set of exercises, users acquired sufficient skill to apply ADS in their own work. Typical areas of application are thick-film hybrid circuit artwork, printed-circuit board layouts, flowcharting of programs, system planning and documentation. Examples of output from ADS are shown in Fig. 2.





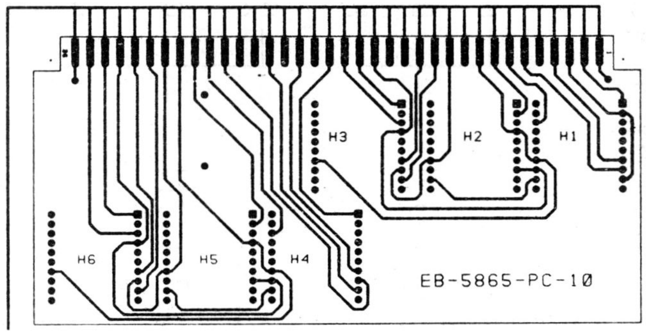


Fig. 2 – Examples of Output from ADS

The Operation Program is related to the day-to-day use of ADS, which is organized as an "open shop" facility. Therefore, good support to the numerous users is essential both in terms of consultation services and system availability. While vendor-supplied service contracts can be purchased, our experience has shown that in-house maintenance and trouble shooting are required in order to guarantee an acceptable level of system availability.

Table 3 summarizes our operating experience with ADS. The CAD Subsystem logged time represents almost full usage of ADS every single-shift working day. At the time ADS was specified, it was estimated that the Artwork Generation Equipment could handle the plotting for four CAD Subsystems. As indicated by the ratio of CAD Subsystem to Artwork Generation Equipment logged times, up to five CAD Subsystems can be accommodated, based on the current availability factors. Availability Factor is defined as:

$$\text{Availability Factor} = \frac{t_a - t_u}{t_a} \times 100$$

t_a = total available time = [8 x number of working days] hour

t_u = system unavailable time = [time lost due to system failures + normal maintenance time] hour

1 NUMBER OF TRAINED USERS: 18

2 TOTAL NUMBER OF HOURS LOGGED:

CAD SUBSYSTEM: 1194

ARTWORK GENERATION EQUIPMENT: 224

3 AVAILABILITY FACTOR:

CAD SUBSYSTEM: 84%

ARTWORK GENERATION EQUIPMENT: 92%

Table 3 – Operating Experience with ADS (June 1972 to February 1973)

Development Program and Future Plans

Studies are currently under way to investigate the application of similar man/machine interface techniques to other activities at CRNL. Initially the main effort will be directed towards areas immediately associated with electronics. As further experience is gained, the work is anticipated to encompass other areas like process engineering, instrumentation for nuclear reactors, control room layouts, etc.

The ADS is also playing a vital role in a study involving the interconnection of different specialized systems, via a network, to form major system assemblies. These problems are of interest, for example, in designing and optimizing electronic systems for future power reactors.

References

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2. S.A. Coons, "An Outline of the Requirements for a Computer-Aided Design System", Vol. 23, p. 299, AFIPS SJCC (1963).