HARDWARE REPLACEMENTS AND SOFTWARE TOOLS FOR DIGITAL CONTROL COMPUTERS

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ABSTRACT

Technological obsolescence is an on-going challenge for all computer use. By design, and to some extent good fortune, AECL has had a good track record with respect to the march of obsolescence in CANDU digital control computer technology. Recognizing obsolescence as a fact of life, AECL has undertaken a program of supporting the digital control technology of existing CANDU plants. Other AECL groups are developing complete replacement systems for the digital control computers, and more advanced systems for the digital control computers of future CANDU reactors.

This paper presents the results of the efforts of AECL's DCC service support group to replace obsolete digital control computer and related components and to provide friendlier software technology related to the maintenance and use of digital control computers in CANDU. These efforts are expected to extend the current lifespan of existing digital control computers through their mandated life. This group applied two simple rules; the product, whether new or replacement should have a generic basis, and the product should be applicable to both existing CANDU plants and to "repeat" plant designs built using current design guidelines. While some exceptions do apply, the rules have been met.

The generic requirement dictates that the product should not be dependent on any name brand technology, and should back-fit to and interface with any such technology which remains in the control design. The application requirement dictates that the product should have universal use and be user friendly to the greatest extent possible. Furthermore, both requirements were designed to anticipate user involvement, modifications and alternate user defined applications.

The replacements for hardware components such as paper tape reader/punch, moving arm disk, contact scanner and Ramtek are discussed. The development of these hardware replacements coincide with the development of a gateway system for selected CANDU digital control computers which use "Varian" technology.

A new software program, Desk Top Tools, permits the designer greater flexibility in digital control computer software design and testing. This software development allows the user to emulate control of the CANDU reactor system by system.

All discussions will highlight the ability of the replacements and the new developments to enhance the operation of the existing and "repeat" plant digital control computers and will explore future applications of these developments. Examples of current use of all replacement components and software are provided.

INTRODUCTION

AECL designs and manufactures a selection of hardware replacements and software tools which are applicable to the CANDU digital control computer (DCC). These replacements can be retrofit to older Varian based digital control computers or used in the design of new "repeat" plants which use Varian based technology for control purposes.

The following hardware is now replaceable with the hardware replacements: moving arm disk, paper tape reader/punch, video display generator, printer and contact scanner. New software tools allow the designer to produce and test programs on a personal computer. Unique combinations of the hardware replacements and the software tools provide even greater flexibility for the control and operation of the plant.

This paper discusses the AECL products which can be used to replace existing control computer hardware and which enhance the operation of the CANDU DCC.

Computers for CANDU Control

Today, CANDU reactors are controlled, with two exceptions, by the Varian-based complement of hardware and associated software. The exceptions, Pickering Nuclear Generating Station A and Darlington, may find some of the developments described in this paper useful for their own purposes. Other Varian-based users may wish to avail themselves of the developments described here as well.

As an example of the evolution of computer technology, one need only look at the Varian computer technology itself. The first Varians were built by Varian Data Machines using 16 bit hardware technology and utilizing assembler for programming purposes. This Varian 600 series evolved to the V7x series (first used in the CANDU in the early 70's) which is the most common computer in use in the CANDU today (Bruce A, Pickering B, Bruce B, Point Lepreau, Wolsong 1, Gentilly 2, and Embalse). Early in the V7x lifespan, Varian Data Machines dissolved and the Varian series of computers devolved to Sperry-Univac who in turn, turned over the Varian series to Second Source Computer Industries (SSCI). This company continued the production of the open architecture design with the SSCI 125 and today the SSCI 890. The former is used at Cernavoda 1, and the latter is used at Wolsong 2, 3, and 4, and will likely be used for the immediate future, in CANDU 6 repeat plant designs. The Bruce A Rehabilitation program is also using the SSCI 890 to replace their existing V7x series of control computers.

Peripheral equipment has evolved concurrently with the Varian based DCC. The earliest designs employ paper tape, and Diablo or Hawk large cartridge disk drives which are used to load and store programs. The majority of display drivers are based on Ramtek. All of these items can be replaced with the modern AECL replacement hardware which can be adapted to the earlier Varian designs and can also be used in the current and future plants which use Varian based technology.

Service Support Group

With the rapid change of computer technology since the late 1970's, designers have felt great pressure to produce good, reliable control designs which take advantage of increasing computer hardware capability and decreasing computer hardware prices ("more bang for the buck"). All the while, designers using this computer technology try to avoid designs which become obsolete in only a few years.

Nuclear power programs, and the CANDU which is our primary focus, are more sensitive to obselescence given the inherent long life spans and exposure to public scrutiny. To address extended life and reliability issues, AECL designers search for and employ computer technology which promises to be the most resistant to obsolescence and which will provide for safe operation and longevity in new and in existing plants.

Some groups at AECL are studying, developing and testing the future CANDU control design[1], while others at AECL, including the DCC service support group, are providing the solutions to resolve current technology obsolescence. All of the groups listen to the users, observe current control developments and evaluate and test the appropriate solutions.

The DCC service support group was formed to address various obselescence questions related to the use of Varian-based equipment, pheripheral hardware and related software. The group noted the evolution of the Varian computer and related equipment, and while this evolution was good in terms of function, there was a need to replace some hardware that, simply stated, would no longer be available to the plants in the future.

Concurrently, it was realized that hardware replacements employing newer technology could enhance the DCC functionality in ways previously unavailable. For example, the capability of storing real time data from the DCC would provide plant operators with large quantities of historical data which could be used for further analysis.

Figure 1a is a block diagram of a typical Varian-based digital control computer system (DCC X and Y). Figure 1b is a similar block diagram showing DCC Z. Both diagrams indicate where the DCC sevice support group has applied the hardware replacements and the software tools. The group realized that all of the components included in figures 1a and 1b could be considered replaceable.

There are limits to replacement, however, most notably need, cost and benefit. The decision was made to focus on that hardware which most needed replacement and to mold any wider design program on this essential focus. If standard commercial replacements were not available or were inadequate, then the group objective was to improve upon the current design and provide this as a replacement or develop a better replacement.

It was recognized also, and this is extremely important to both any replacement program, and the long term health of the Varian based DCC, that the existing control software should remain essentially unchanged and should be maintainable through any and all changes to the digital control computer hardware. If a decision were made to change to a different hardware platform not based on Varian technology, costly software replacement would result. Such a move could incur significant costs to verify and validate executive and applications programs for the digital control computers in existing and future repeat plants. The DCC service support group has paid particular attention to this situation by developing software tools to facilitate work with DCC control software, and to encourage CANDU plants to utilize these tools. Typically the group addresses problems of obselescence by combining a hardware replacement and a software tool as shown in figures 1a and 1b.

The operational principle of AECL's DCC service support group is to focus on generic solutions and applications. Hardware replacements and software tools are described below with references to their current uses. For simplicity purposes, combined solutions are described under hardware replacements.

HARDWARE REPLACEMENTS

Parallel Data Link Control Card

The Parallel Data Link Control Card (PDLC) was the first development and has one of the most useful applications in the hardware stable of products. Figure 3a shows the PDLC card uninstalled. The PDLC functions as an interface between the DCC and a personal microcomputer. The PDLC can be used for moving arm disk replacement and for a gateway to other computers or local area networks.

The PDLC is installed in a personal microcomputer (PC) and connects to a BIOC card in the VARIAN-based DCC. Once the hardware connection is complete, communication between the Varian-based computer and the PC can be accomplished provided that appropriate software changes are made in the DCC, and a suitable application program is available in the PC. The PDLC provides two immediate enhancements for current users of the Varian based digital control computer. With the connection to a PC, and appropriate software installed, the PDLC can act as a gateway for remote processing or it can act as a storage device for the Varian system, providing interactive storage space. First, it provides a gateway for remote processing. For example, data collected by the DCC can be transmitted to and stored in a PC either for immediate analysis with appropriate programs or subsequent analysis of the stored data. This opportunity is exciting because it can permit examination of all of the real-time data which was observed in the controlling DCC. Second, the use of a PDLC permits the replacement of the moving arm disk as installed peripheral equipment in the DCC, replacing one more piece of obsolete hardware, figure 2c. The group considers the latter application a combination enhancement because some software work is required to adapt the system to the particular configuration of the designated plant. The designated plant may create their own software, if they elect to do so, and the group obliges requests for assistance from users seeking help to design this software. Currently this combination enhancement is called either the Off-Line or On-Line Emulated Moving Arm Disk (EMAD) system depending upon the mode of operation.

While the PDLC is designed to link the original Varian and SSCI family of computers to a PC, the PDLC can be adapted to link other computer designs. Currently, the group has identified DEC and VME bus based computers for this capability, and invites an opportunity to demonstrate the connection.

Paper Tape Reader/Punch Emulator

Following lockstep with the PDLC was the necessity to replace the paper tape system. The Paper Tape Emulator (PTE), figure 3b, replaces the original paper tape reader/punch device, figure 2b. The PTE requires no software changes within the DCC to operate. The DCC "sees" a paper tape reader punch where the PTE is installed. The replacement of the paper tape system fits with another objective of the group, that is, to be able to revise and test control programs off-line and at the designer's work station without the use of the digital control computer. This fundamental requirement dictated that the paper tape replacement be founded on technology most common to a developer's desk; the PC. The 3½ inch floppy disk was chosen as the basic storage device used in the PTE design.

The PTE occupies less than half of the current vertical space occupied by existing paper tape reader/punch devices. The PTE accepts the identical input and output cables of the paper tape reader/punch assembly.

Initially, for users who chose paper tape replacement, AECL loaded their DCC operating programs onto the floppy disk from either paper tapes or from a core dump on a large cartridge disk supplied by the user. Today, the PTE is ordered primarily without pre-loading because operations staff find the PTE so simple to operate that they can load their own programs and often prefer to do so.

Ramtek Replacement

The Ramtek display system has had a reputation for being rather maintenance intensive and difficult to repair. Figure 2a shows the components in one chassis of a Ramtek containing four channels. The size and the physical complexity of these component boards illustrate the potential benefits of replacement. The Video Display Generator (VDG), figure 3c, the group's most recent product, replaces the Ramtek with no change of software within the DCC. The VDG can be mounted in the space vacated by the old Ramtek. The VDG occupies about one-half of the Ramtek space. The VDG merges the power of a pentium microcomputer with carefully written software to produce a response which is virtually identical to the old system. The VDG also incorporates many new features which operations will find particularly useful. For example, the VDG will support a completely new display instruction and character set if required. The user may define a set of custom graphic instructions to enhance the display. All VDG display commands are software based. Complicated static displays can be prepared and stored separately. When required they can be displayed, with the dynamic data received from the DCC filling in the blanks in a seamless operation.

Printer Replacement

AECL has developed a Printer Hardcopy Controller (PHC) and Long Line Driver Receiver (LLDR), figures 4a and 4b, to replace older electrostatic printers. The PHC installs in the I/O expansion chassis of the Varian based computer and connects to an IOBIC. The LLDR installs in the replacement printer. The replacement printer can be chosen by the user from various off-the-shelf printer types with a few limitations to prevent the selection of inappropriate models for this operation. The selected printer can be located up to a distance of 60 meters away from the DCC. Minor software changes are required in the operating system of the DCC to incorporate this printer change. The obvious advantage of this change is the conversion to plain paper and standard toners with no loss in efficiency of printing.

Prom Boot Card

The Prom Boot Card (PBC), figure 4c, provides the ability to boot and load the DCC with programs stored in EPROMs mounted on the PBC. The PBC plugs into the Varian expansion backplane to replace the paper tape reader/punch, and uses the same bus address as the paper tape reader/punch. The Paper Tape Emulator, described above, is the recommended replacement for the paper tape reader/punch, however. The PBC is a low cost option for users who opt for an EPROM based boot capability.

Contact Scanner

The original contact scanner manufacturer, ESE, was purchased by another company which decided that the contact scanner was not a business line they wished to retain. AECL obtained the rights to manufacture the contact scanner and has upgraded and expanded the design to incorporate new features for the users. AECL has reconstructed the 1300 and 1500 series of components and is currently able to adapt many of these parts to other contact scanner types. Table 1 lists the component boards now available. Figures 5a through 5g show the components.

While retaining compatibility with the old design on a board by board basis, the new design permits expansion of the number of input points beyond the current 2048 point limit while manitaining the loop time of 4 ms. Maintenance of the new boards is simplified because the components of the new boards are readily available. If required, a complete contact scanner can be constructed to replace any existing and obsolete system.

Other Parts

AECL also makes replacements for miscellaneous parts including buffer amplifiers, watchdog modules, and voltage dividers, to name but a few. It is recognized that users often do not have the time or the resources to locate or design identical replacement parts for electronic based systems. Therefore, queries are invited from all CANDU facilities who may be interested in replacing any computer related component which is considered obsolete or which they believe may become obsolete in the next few years. Frequently, parts are found or can be made inexpensively, thereby saving the user high development and replacement costs for entire systems.

Software Tools

AECL has developed some interesting and useful software tools to support DCC software and hardware development and testing. The tools provide for the seamless interface of existing DCC software and new replacement hardware. For example, EMAD was described above under the PDLC section as a combination replacement hardware and software tool. Another combination is the PHC and LLDR.

For the software designer, the group has created Desk Top Tools. The Desk Top Tools allow designers to code, assemble, link, debug, and perform subsystem integration testing on a workstation in the office environment. The tools have been used successfully for the Wolsong 2, 3, and 4 project, for the Pickering B Gateway system, for the Bruce B Executive unit testing, and for the Institute for Advanced Engineering DCC emulator.

These Desk Top Tools include:

- Varian Cross-Assembler and Cross-Linker
- Fixed Head Disk (FHD)/ Megaram Manager
- DCC File Access System (FAS)
- DCC Emulator

The Varian Cross-Assembler and Cross-Linker are fully compatible with DCC DOS counterparts. They are very fast and produce identical assembled listings and binary images.

The FHD/Megaram Manager provides all of the functionality required to access the emulated FHD/Megaram. It was designed to manage all DCC FHD images in the PC. Together with the EMAD system, the actual DCC FHD image can be saved as a single PC file which can be used directly with the DCC Emulator or for DCC software configuration control.

FAS programs are designed for the EMAD system. They provide a friendly interface for DCC designers to access

EMAD files. A group of files can be exchanged easily between the PC and the EMAD.

The DCC Emulator program is ideal for testing both off-line and on-line software. It provides detailed emulation of all Varian instruction sets and most DCC peripherals. It has successfully run Pickering B, Gentilly 2, Wolsong 1, Bruce B and ENTC DCC software. Since it emulates all Varian instructions, it is ideal for testing the DCC Executive as well as any DCC application program. The designer can perform static as well as dynamic testing. The group uses the DCC Emulator extensively for product development and testing. A good example with details of the use of the DCC Emulator can be found in reference 2.

Future Services

Currently, AECL's DCC service support group is planning the upgrade of certain of their hardware replacements described above and a significant software tool implementation.

Hardware replacements will include an option to replace the floppy disk of the PTE with a PCMCIA flash card. Other contact scanner parts will become available. Parts for non-control components will also become available.

Work is currently underway to extend the existing DCC Emulator program to include support for the SSCI 890 computer. Coupled with this is a plan to enhance the DCC emulator by adding I/O capability to act as a limited scope desk top simulator.

Conclusion

AECL's DCC service support group is pleased that its hardware replacements and software tools have been so widely received and used by those using Varian based control technology; whether these products have been involved in development, in test, or in operation.

An important observation which has emerged from this work is that one can rarely make a hardware change without affecting software. Nor software changes without affecting hardware.

The flexibility of the CANDU design has provided AECL with the opportunity to prevent obsolescence in the Varian based digital control computer design using replacement hardware and software tools.

Acknowledgements

The efforts of the following staff who perform major roles in the work of the DCC service support group are hereby acknowledged; D. Bailie, B. Montgomery, R. Polimeni, T. Unrau, and H. Woods.

References

1. MacBeth, M.J. and Webster, A. "Improved Operability of the CANDU 9 Control Centre" 1996 April, Proceedings of the 11th KAIF/KNS Annual Conference, Seoul, Korea.

2. McDonald, A.M. et al., "Development of DCC Software Dynamic Test Facility-Past and Future" 1996 June, Proceedings of the 17th CNS Conference, Fredericton, New Brunswick, Canada.

TABLE 1: CONTACT SCANNER PARTS

ESE Part No.	Description	AECL Part No.
1380	Regulator Board	66450-00-2-2-001-1380
1381	Interface Board	66450-00-2-2-001-1381
1569	Sub-Scanner Board	66450-00-2-2-001-1569
1573	Central Scanner #1 Board	66450-00-2-2-001-1573
1574	Central Scanner #2 Board	66450-00-2-2-001-1574
1567	Sub-Scanner Power Supply	66450-00-2-2-002-1567
1576	Central Scanner Power Supply	66450-00-2-2-002-1576

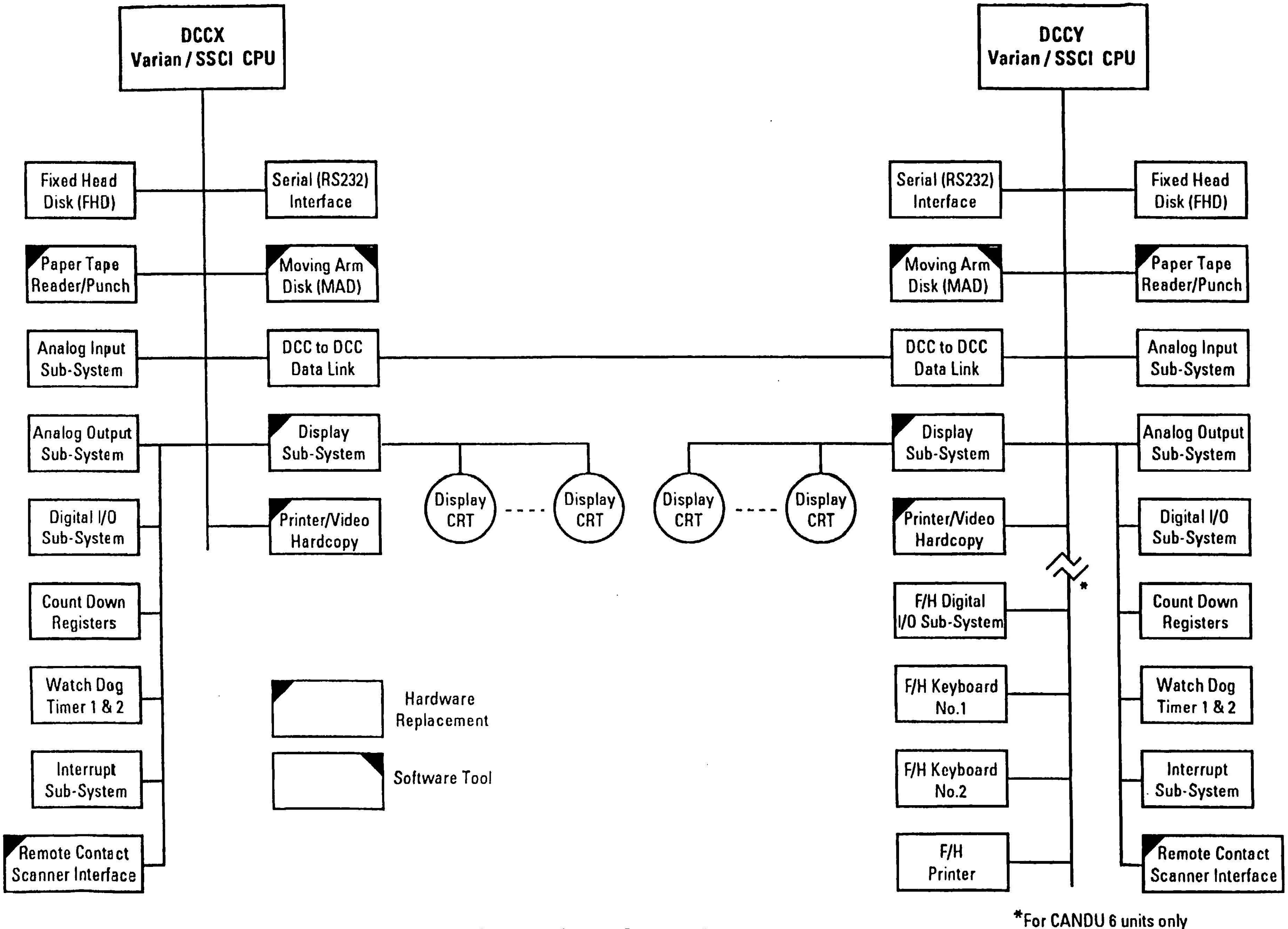


Figure 1a: BLOCK DIAGRAM OF TYPICAL VARIAN-BASED DIGITAL CONTROL COMPUTER SYSTEM (DCCX & DCCY)

960464-3R1

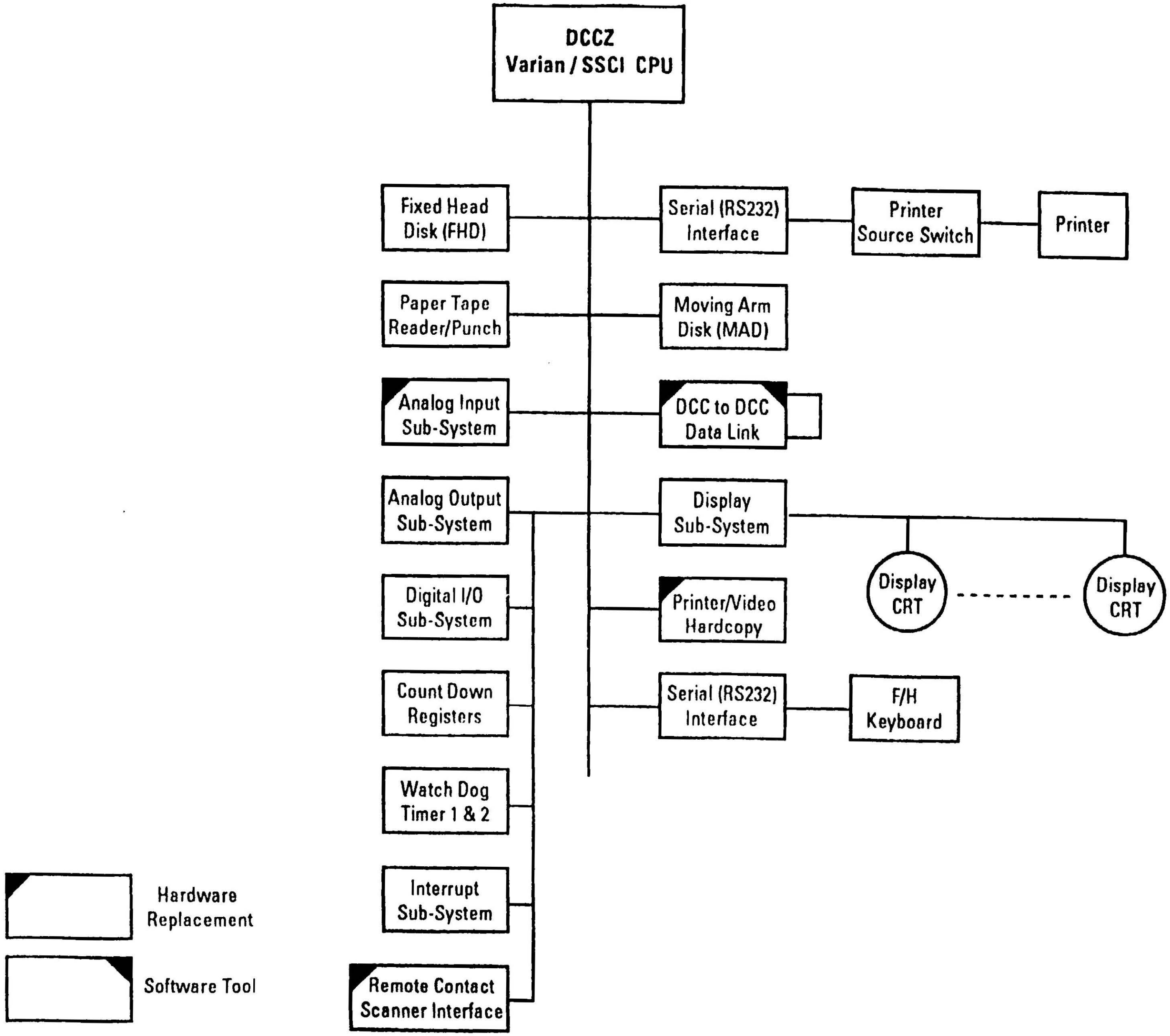


Figure 1b: BLOCK DIAGRAM OF TYPICAL VARIAN-BASED DIGITAL CONTROL COMPUTER SYSTEM (DCCZ)

960464-2B2

Figure 2a
Ramtek Video
Display Generator
Serving 4 Channels

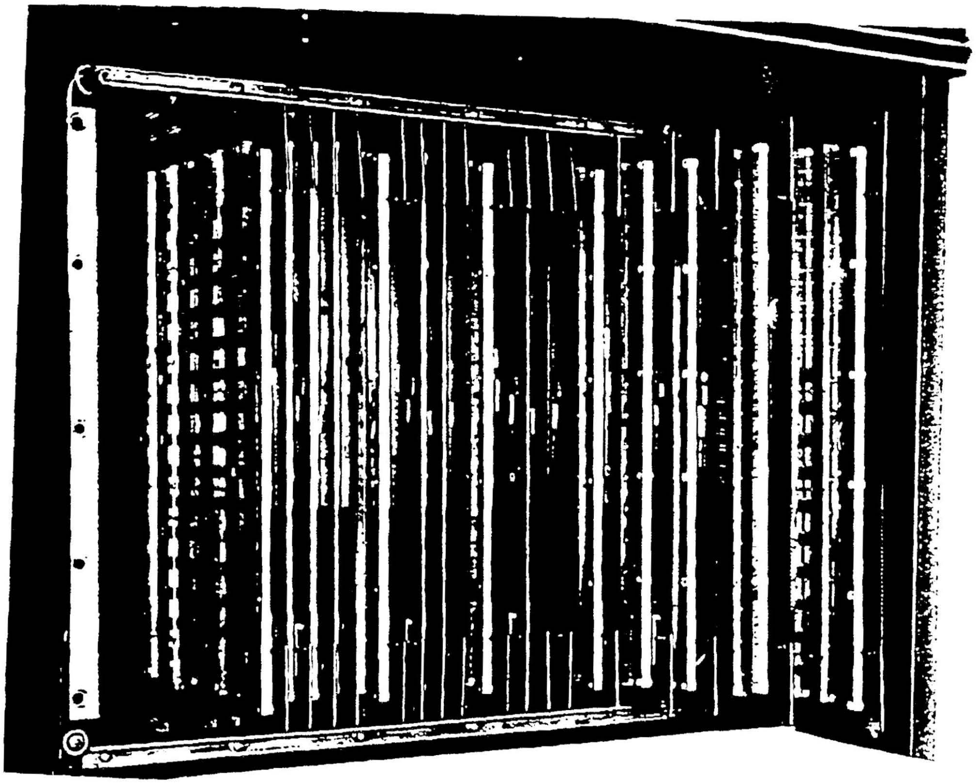


Figure 2b
Paper Tape Reader/Punch

Figure 2c
Diablo Hard Disk Drive Above
Open Hawk Drive

Figure 3a
Parallel Data Link
Control (PDLC) Card

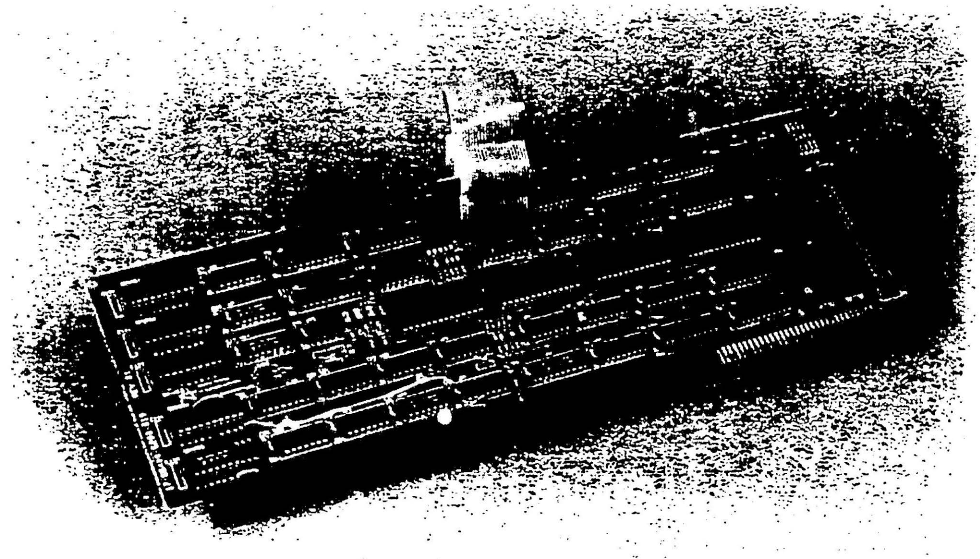


Figure 3b
Paper Tape
Emulator (PTE)

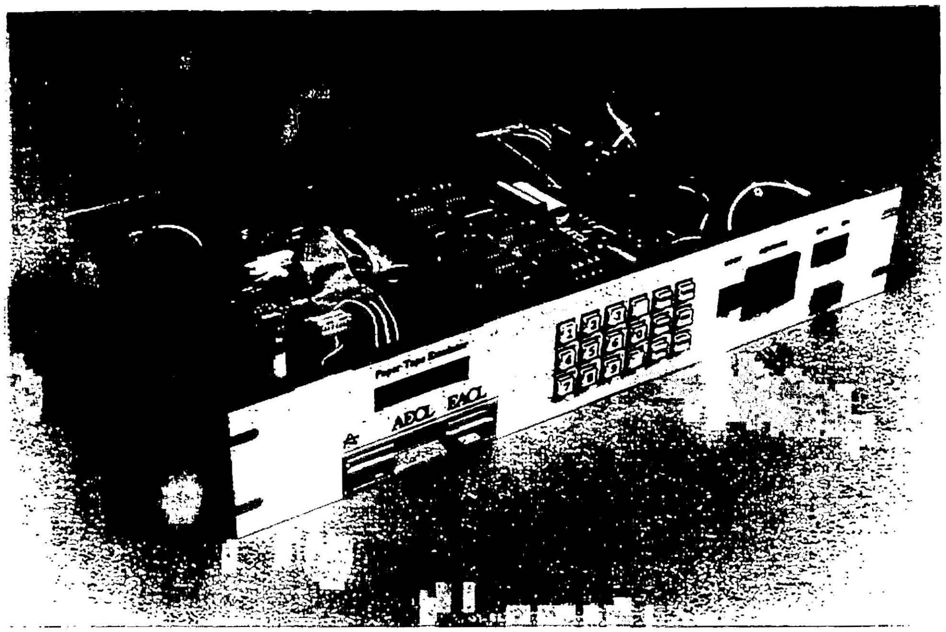
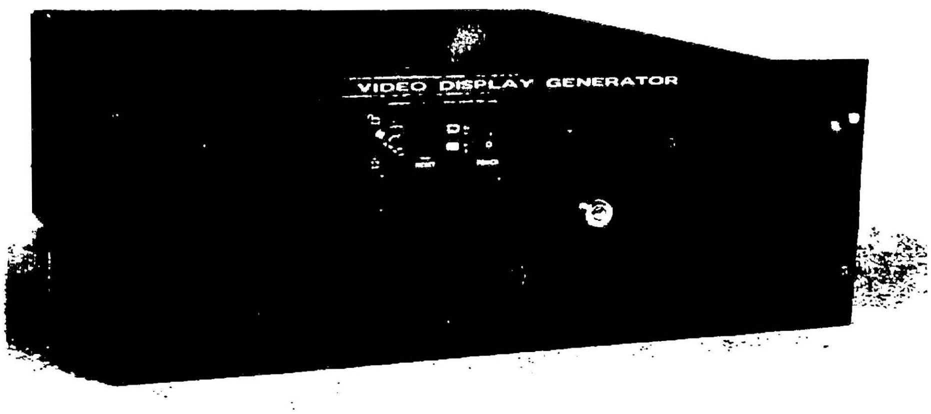


Figure 3c
Video Display
Generator (VDG)



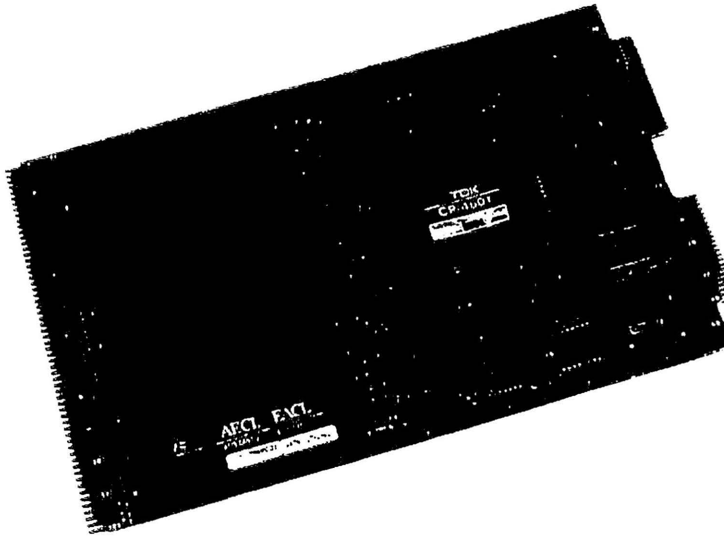


Figure 4a
Printer Hardcopy
Controller

Figure 4b
Long Line Driver
Receiver

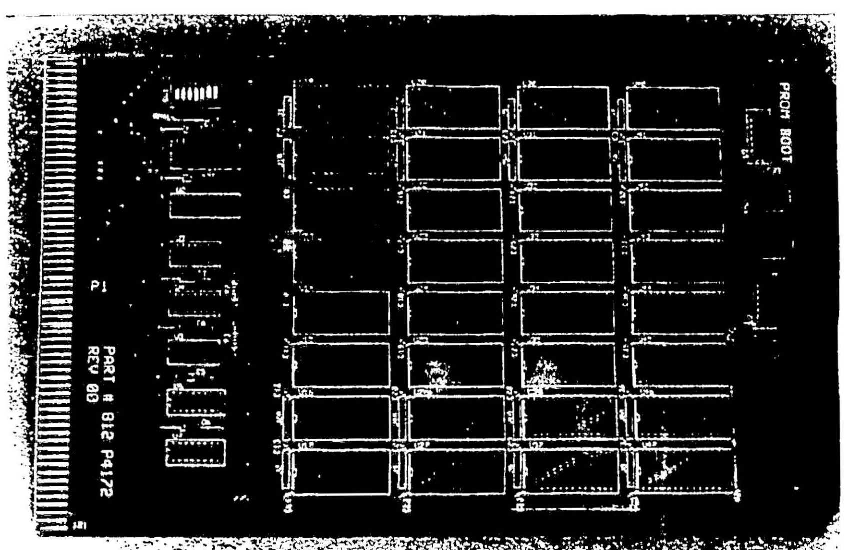


Figure 4c
PROM Boot Card

Figure 5a
Sub Scanner
Power Supply

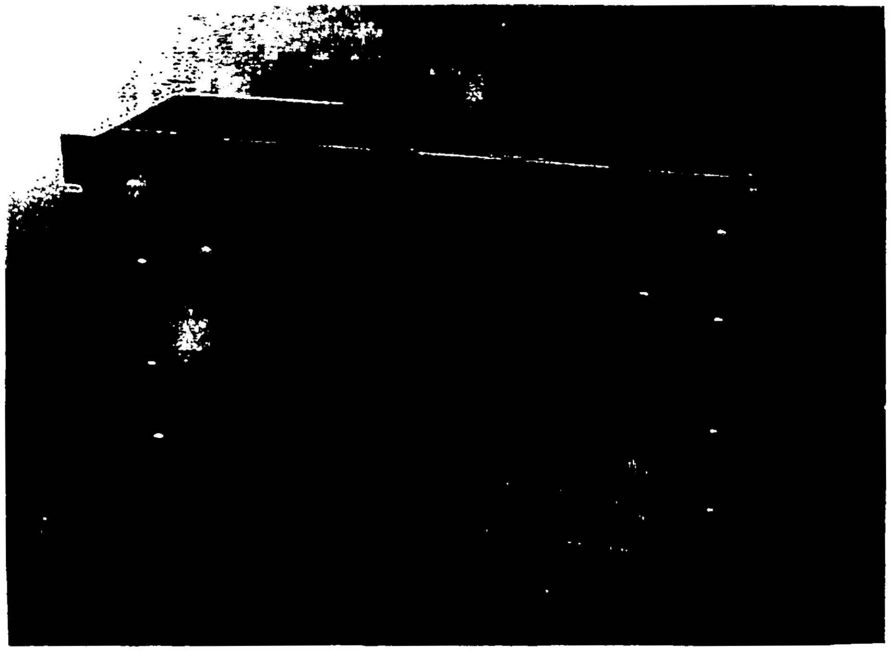


Figure 5b
Central Scanner
#2 Board

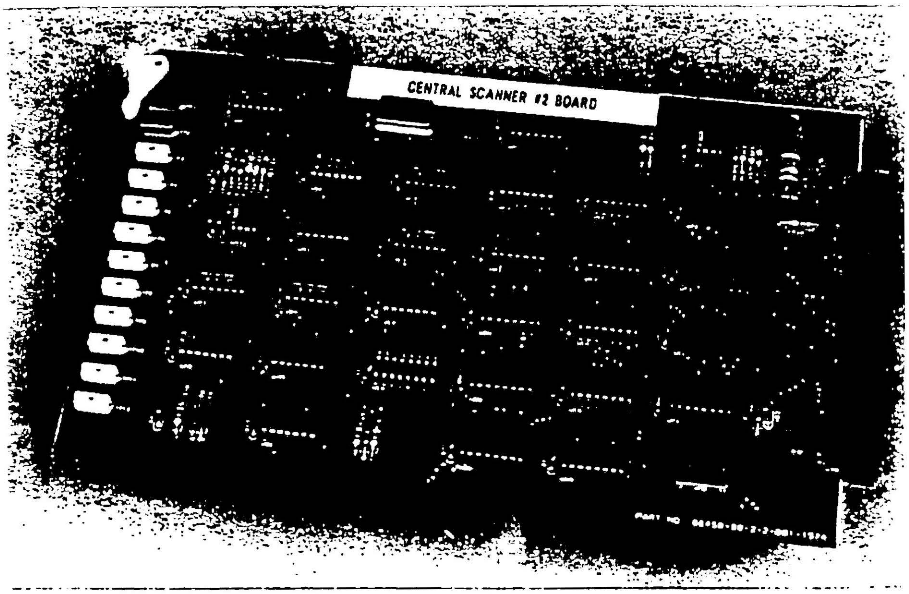
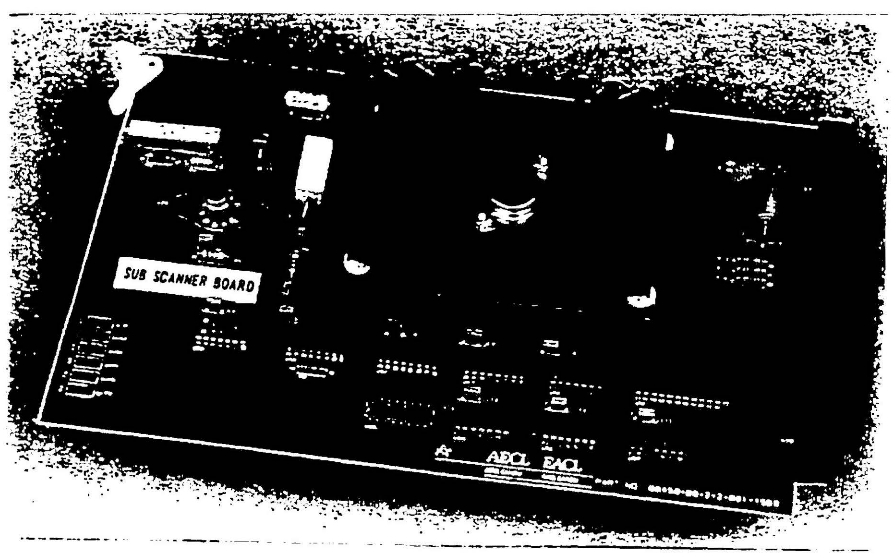


Figure 5c
Sub Scanner Board



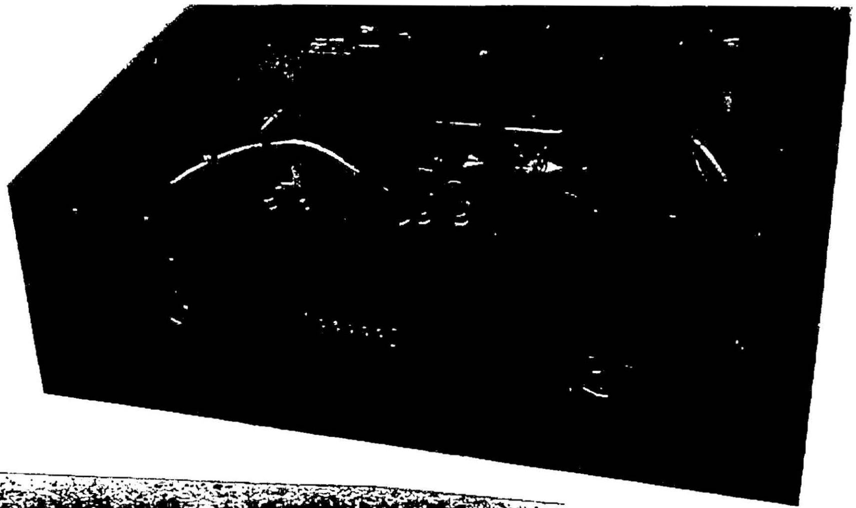


Figure 5d
Central Scanner
Power Supply

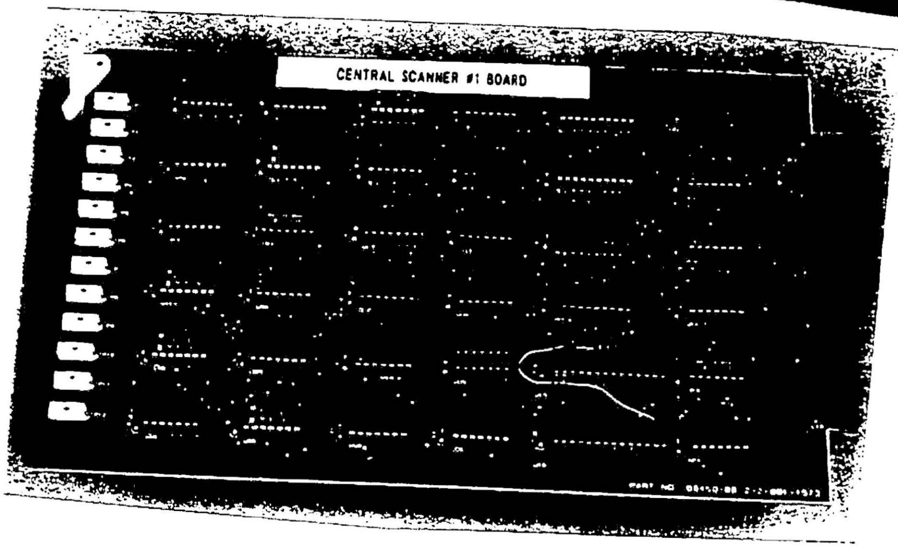


Figure 5e
Central Scanner
#1 Board

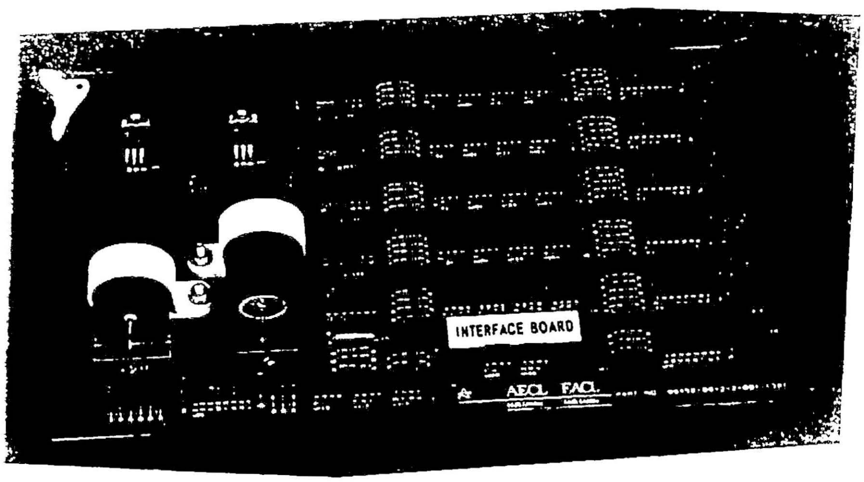


Figure 5f
Interface Board

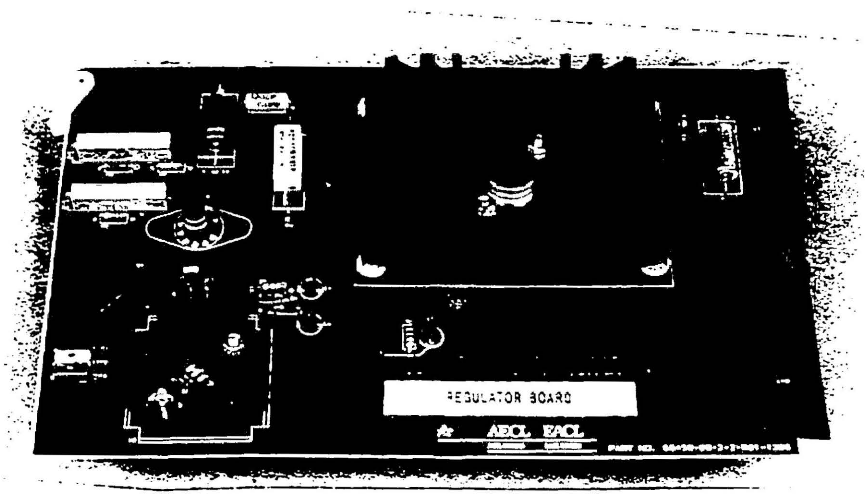


Figure 5g
Regulator Board