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THE SUPPORT AND UTILIZATION OF THE LSI-11 PROCESSOR FAMILY AT SLAC*

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ABSTRACT

Microcomputer systems based on the DEC LSI-11 processor family have been in use at SLAC for five years. They are used for a wide variety of applications.

The support of these systems is divided into three general areas: engineering, maintenance, and software. Engineering specifies the system to match user requirements. SLAC has been able to design one general purpose system which can be tailored to fit many specific requirements. Maintenance provides system and component diagnostic services and repair. Software support includes software consulting services, assistance in systems design, and the development and support of special purpose operating systems and programs.

These support functions are handled as subtasks by three teams in the SLAC Electronics Instrumentation Group. Each of these teams utilizes several LSI-11 systems in the performance of its primary tasks. They work closely together to jointly provide overall support for the larger SLAC community.

INTRODUCTION

The Stanford Linear Accelerator Center (SLAC) is a National Laboratory dedicated to basic research in high energy physics. Staffed and operated by Stanford University for the United States Department of Energy, SLAC employs about 1300 people.

Figure 1 is of an abbreviated organizational table of SLAC. The groups mentioned in this paper are shown, along with the abbreviations which are used herein. Of special interest is the direct interaction link between the users and support staff at the lowest level of organization.

SLAC has long had a need for a programmable test and control module which is low in cost, portable, CAMAC compatible, reliable under a wide range of environmental conditions, and easily adapted to many different situations. That need is satisfied by a microcomputer system.

Microcomputers based on the DEC LSI-11†,¶ microprocessor family[1] were first introduced at SLAC in early 1976. Over the following two years, as software was developed at SLAC, their use spread. In those early years each group was responsible for purchasing their own boards and assembling their own systems.

In early 1978, the Electronics Instrumentation Group (EIN) took note of the LSI-11 capabilities. EIN started an evaluation of the microprocessor systems available. The LSI-11 was chosen even though the unit cost may have been higher than some other units. The primary factors in this decision

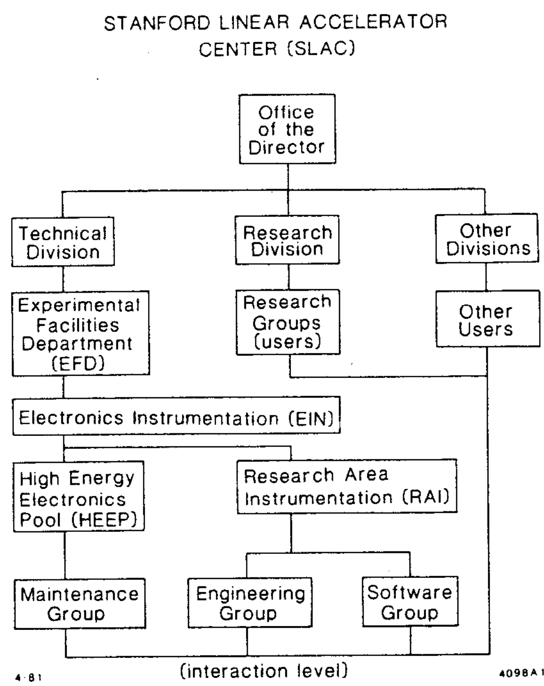

Fig. 1. Abbreviated table of organization, showing that portion of the SLAC organization covering the groups mentioned in this paper.

* Work supported by the Department of Energy, contract DE-AC03-76SF00515.
† DEC and VAX are registered trademarks of the Digital Equipment Corporation.
¶ LSI-11 hereafter refers to LSI-11, LSI-11/2 and LSI-11/23 processor systems.

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were the availability of the hardware components, and the software support available, both in general and at SLAC in particular. Research Area Instrumentation (a subgroup of EIN) then undertook the task of developing a standard LSI-11 package. In mid-1979, LSI-11s packaged in the evolving SLAC standard chassis were made available through the High Energy Electronics Pool (HEEP), just like other modular electronics equipment.

Presently there are 40 LSI-11 systems in operation at SLAC. Of these 9 are used for research and development in hardware and software, 5 are used for equipment maintenance and test, 8 are used for operational support of various areas of the accelerator facility, and 18 are in use by the research groups for data acquisition and control in experiments.

LSI-11 SUPPORT STRUCTURE

There are several computer maintenance groups at SLAC. The central computer facility has an operations and maintenance group for the large computer complex. Data Analysis has a maintenance group which concentrates on the VAXs† and minicomputers. Other groups, such as the Positron-Electron Project at SLAC (PEP), and the Instrumentation and Control group, each with large numbers of control computers, have their own maintenance groups, plus outside contract services.

LSI-11 systems are usually operated by groups which have their own programming staff. Some groups include individuals with sufficient hardware knowledge to isolate a problem to the computer or the connected equipment. From this point, however, assistance for further problem diagnosis and repair is usually required.

There are three general types of computer-related problems. These are: hardware, software, and the more difficult combination of hardware and software. Basic hardware maintenance requires technicians, often with special training. Many software problems require systems programmers/analysts, with experience in program coding and debugging at machine-code levels. Hareware/software interactive problems often require knowledge in both areas. It is usually difficult to find a single individual with the skills necessary to solve major problems in all areas. Where an application requires custom hardware and software design, a team of software and hardware experts is often needed.

The existence of these skill divisions directed the development of the LSI-11 support structure. The present structure has evolved through the efforts of many people within EIN working together to provide the needed support.

Currently the support of the LSI-11 systems is handled by three subgroups of EIN: HEEP (Maintenance), Engineering, and Software support. In the discussion that follows, it is important to note that the support of LSI-11s is not the primary task of any of these groups. However, each group regularly uses LSI-11 systems in the performance of its jobs.

MAINTENANCE SUPPORT

The SLAC High Energy Electronics Pool (HEEP) provides a wide range of support. A broad spectrum of commercial and in-house designed high-speed logic modules are available such as NIM bins and CAMAC crates, crate controllers, data acquisition modules, scaler scanners and displays, printers, high-voltage distribution systems, high-voltage phototube power supplies, and pulse-height analyzers.

HEEP has a number of LSI-11 systems which are used for the test and maintenance of its electronic equipment. It also owns several systems which are loaned to users on a short-term basis for test and experimental use. Experimenters needing an LSI-11 system for longer than six months are asked to purchase one.

All new systems are ordered through HEEP. The maintenance group procures, assembles and delivers the systems, maintains the spares stock, and performs almost all first-line failure diagnosis and repair. In addition, Maintenance specifies the hardware and software tools needed to perform test and repair functions. The specified tools are often provided by the engineering and software groups, and Maintenance acts as the primary test facility for them.

All initial contacts for hardware services are made through the maintenance group. This includes requests for new systems, maintenance, reconfiguration or installation, etc. The single-contact approach simplifies service for both the user and the support groups. At times Maintenance will use the engineering or software personnel as consultants on a specific problem, but this is transparent to the user.

HEEP provides maintenance for all of the equipment it supplies. In general the equipment must be brought to the HEEP lab for servicing. Field service calls are made when necessary. Service is provided for LSI-11 components and peripherals which are HEEP inventoried and identified. These include the LSI-11 chassis, Q-BUS cards, printers, terminals, floppy-disk drives, crate controllers and crate access modules. Other SLAC-owned LSI-11 systems, inventoried through HEEP, are maintained in the same manner as the HEEP-owned loaner systems.

ENGINEERING SUPPORT

Engineering is the electronics design group for EIN. The group produces designs varying in complexity from simple-function circuits to complete systems. Engineering is responsible for prototype construction and test, often including the development of software to perform the needed tests. The group's hardware functions include the design and construction of special cards, chassis, packaging, and system hardware, and the evaluation and selection of commercial equipment. The group also oversees the pre-production runs on quantity construction, including the procurement of any necessary special components. Engineering estimates and evaluates costs at all levels, from discrete components to full systems. Engineering also has the responsibility for seeing that all parts of the systems are maintainable, and that the necessary hardware and software required to perform that maintenance are provided.

Engineering has many differing LSI-11 responsibilities. These include the design of the systems chassis, the specification of a system to match user requirements, special designs as needed, and the overall responsibility for keeping these systems

† DEC and VAX are registered trademarks of the Digital Equipment Corporation.

operational. To meet this responsibility, Engineering acts as a consultant for Maintenance, assisting in the evaluation of hardware problems, and modifying hardware designs to eliminate the problems. This may include the design modification of commercially supplied equipment, normally coordinated with the manufacturer.

This group also assists with the support of equipment in use at SLAC that cannot be routinely serviced by the maintenance group. This usually occurs only for some items of peripheral equipment (i.e., non-SLAC tape drives brought to the site by a visiting research group), and often requires locating an outside service facility to perform the needed maintenance. Although the preference is to have the owning group perform the necessary coordination with the outside facility, for some problems the coordination is done by the engineering group.

Engineering may act as liaison between a user and the maintenance or software groups. Engineering also acts as a consulting service for the software group in the diagnosis and test of special application production programs. All three groups work together on various projects and problems.

SOFTWARE SUPPORT

The Software Support Group provides software consulting services, assistance in the software aspects of system and interface design, and programming assistance and services for the physicists, engineers, technicians, and other support staff of the Experimental Facilities Department. The programming support provided often includes the development of special purpose operating systems and applications programs for use with hardware designed by EIN for the general SLAC community.

The LSI-11 software support, provided for EIN, is also available to the general SLAC community. This includes consulting services, information on LSI-11 software development facilities, and the support of some general purpose systems software.

When an order is being considered for an LSI-11 processor, chassis and components, the ordering user consults with an engineer and a programmer. The user describes the application and is presented with documentation on the hardware and software available. The system configuration is normally established at this time. It is recommended that each system be equipped with 4K words of EPROM kernel, usually referred to as the KERNEL.[2]

The software documentation includes information about the software development facilities available. The most widely used facility resides on the SLAC central computer system (known as the TRIPLEX).[3] By utilizing the KERNEL and the cross-compilers and cross-linkers available on the TRIPLEX, the user can create software which can be down-loaded from the TRIPLEX into the LSI-11 RAM.[2] For RT-11,[4] SLAC developed documentation and utility programs for communicating with the TRIPLEX are available. The user is responsible for obtaining a copy of RT-11. Documentation for a SLAC version of FORTH, system disks, and samples of FORTH source code are provided.

The systems software available includes the KERNEL program, which is provided and maintained for the general SLAC community. At various times, the communications protocol to the SLAC central computer system may change. When modifications are necessary, the EPROM KERNEL code is updated, and a master set of EPROMs is given to Maintenance which is then responsible for upgrading the systems in the field. Software support also maintains several libraries of utility routines on the central SLAC computer. Included are histogram and display routines, console interaction routines, and some basic operating systems which utilize these routines. These operating systems can be tailored by the user to suit a particular application.

Software support also has available a diagnostic package for hardware. The major component of the package is a set of diagnostics for memory and peripherals which are written in FORTH. Tests are included for peripherals such as the CAMAC crate controllers and interfaces, disk and tape drives, DLV11-Js, and the various memory systems available. Also included is information on the DEC LSI-11 diagnostics.

With the assistance of the Engineering and Maintenance staff, the Software Support Group maintains an LSI-11 software and firmware development facility. The facility includes PROM burners, tape-to-floppy and floppy-to-tape data transfer facilities, floppy-to-TRIPLEX and TRIPLEX-to-floppy data transfer facilities, and paper tape reader/punch facilities.

SUPPORT SUMMARY

The pooling of the support personnel into one central group reduces the total manpower needed to support the many diverse systems. Also, each user group does not need to maintain its own spares stock. In addition, a centralized source of LSI-11 information improves service for the users, and minimizes the duplication of effort in the hardware and software areas.

A major advantage at SLAC is the structure of the central support organization. This provides the full-time support for the LSI-11 systems. Several individuals from Maintenance, Engineering, and Software provide this support, each person on an as-required basis. This structure gives the support group a much wider manpower base than that of a dedicated support group. More individuals work with the different systems and components. Each gains knowledge and expertise of many different installations. Thus more people are usefully available when assistance is required. Any equipment connected with the actual running of experiments, where delays would cause a loss of experimental hours, is given priority service when problems occur.[5]

THE STANDARD SLAC LSI-11 CHASSIS

The current support structure and system chassis developed in parallel. In addition to user requirements, the needs of the maintenance and software groups were major factors in the chassis specification. The chassis presently in use enables EIN to meet the needs of the SLAC microprocessor user community. The design affects both the hardware and software servicability of the systems. This section describes the evolution of, and presents some detailed information on, the design and function of this chassis.

The first LSI-11 microcomputers at SLAC were fairly simple. They utilized the quad-wide LSI-11 processor, 4K words of 2708 EPROM, 24K words of RAM, and 2 DLV11 interfaces.[6] One of the DLV11s was used to interface to the console terminal and the other was used to interface to the TRIPLEX. The 4K words of EPROM contained the TRIPLEX serial line and console terminal handlers. Later a Schlumberger JLSI-10 (Ref. 7) CAMAC crate controller and interface were added.

Early SLAC packaging used commercial quad-wide cardcages and various SLAC-built custom chassis, including a wide variety of power supplies. In effect, each chassis was unique, with very few interchangeable components other than the processor and memory boards. Some user groups purchased commercial system enclosures which included the cardcage and power supplies. In 1978 RAI began an evaluation of then available commercial enclosures. It soon became apparent that no available enclosure was suited to the special requirements of the SLAC community.

These special requirements included ease of field exchange at both the board and chassis level, ease of access to interface cables, moderate-to-high power supply capability, and high system reliability. The reliability requirement alone meant that a high-quality power supply and cooling fan(s) be included in the enclosure design. The system power requirement, coupled with heating effects within the enclosure, soon pointed to the need for a switching-style power supply, generally more efficient over the full operating range than a corresponding linear power supply. No known commercial chassis, at that time, met these requirements.

In early 1979 it was decided to design a custom enclosure for SLAC. At that time the dual-wide microprocessor and peripheral boards were becoming readily available. A variety of cardcage styles was also available. Prototype chassis were designed and constructed utilizing three different cardcages. These were two dual-wide cardcages, an 8-high and a 12-high, and an 8-high, quad-wide cardcage. The first approach was to use the dual-wide cardcages as the most efficient packaging for most systems, with the quad-wide cardcage being used only in those systems requiring one or more quad-wide boards. Several units of each type were constructed, and placed in service for evaluation.

It was soon found that the chassis with the quad-wide cardcage was the preferred choice. Two reasons were found. These were the growth of systems beyond the 8-card limit of the smaller dual-wide cardcage, coupled with the users' rejection of the added rack space requirement imposed by the 12-high chassis.

About the time that RAI started to design and define a standard for the LSI-11 systems at SLAC, the dual-wide LSI-11/2 processor, DLV11-J 4-port serial interface,[5] and the Standard Engineering CC-LSI-11 (Ref. 8) CAMAC crate controller and interface became available. In the SLAC standard chassis, they were substituted for the quad-wide LSI-11 processor, DLV11s, and the Schlumberger CAMAC crate controller modules.

Currently, the user has the choice of an LSI-11/2 or LSI-11/23 as the processor. Each system includes a DLV11-J 4-port serial interface configured to the SLAC standard. The memory system supplied depends upon the system application. Peripherals optionally available include double-density dual-drive floppy-disk units, tape drives, line printers, CAMAC crate controllers and interfaces, cartridge tape units, and any other commercially available devices the user may wish to order.

The current SLAC microprocessor enclosure[9] is a rack-mount chassis with slides. This enclosure is commonly referred to as the "MK II Chassis" (Fig. 2). The cardcage is a commercial 8-high, quad-wide, 16-slot assembly.† A high-efficiency switching power supply will easily operate a broad range of microprocessor and peripheral cards. Either of two commercial power supplies may be installed.§ A pair of 100 CFM fans provide the necessary air flow for the cards and power supply. Four printed circuit boards are used for system control and basic ASCII-port interfacing. The chassis top cover is designed to mount in the rack rather than on the chassis. Thus the unit is enclosed when in the rack, but when slid forward for access it is immediately exposed without having to remove the cover.

The four chassis PC boards are:

1. the front panel board (Fig. 3) which mounts all displays and control switches except the main AC power circuit breaker;

‡ Manufactured by Netcom.

§ Manufactured by Sierracin Power or Gould.

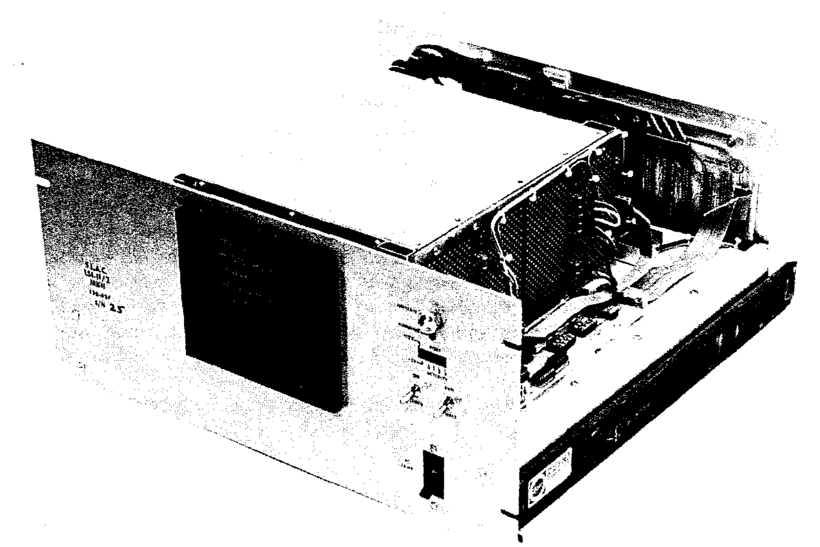

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Fig. 2. MK II Chassis, oblique view.

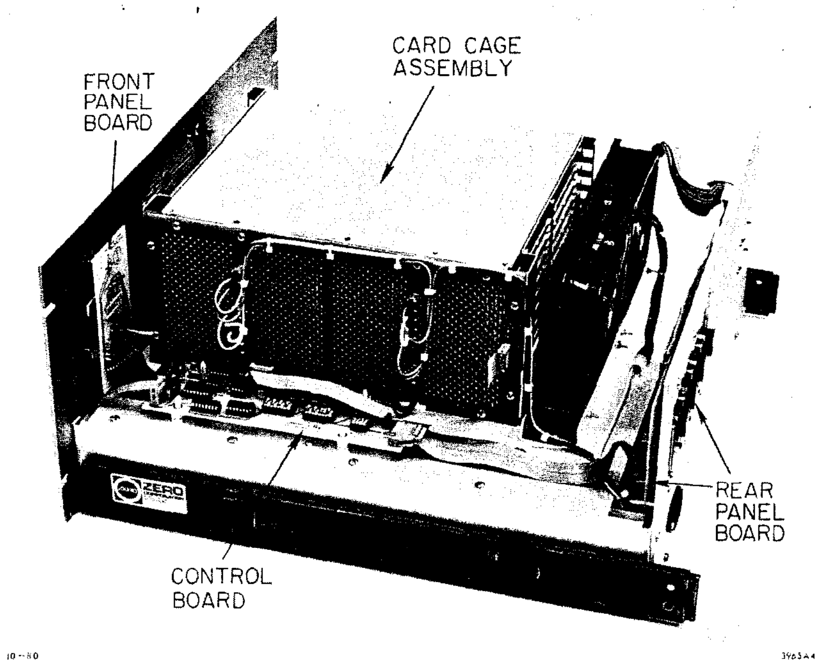

Fig. 3. MK II Chassis, side view.

2. the system control board (Fig. 3) includes switch debounce circuits, display drivers, port activity monitors, power fail monitor, and four variable baud-rate generators;
3. an ASCII-port interface board (the back panel board) which converts from flat ribbon cable to standard 25-pin male D-connectors (Figs. 3 and 4);
4. and the line-time-clock generator board. This board derives the line clock from 120 VAC power. For safety reasons this board is located in the screen covered area on the bottom of the chassis, along with all other AC circuitry. Thus no hazardous voltages are exposed, even during normal maintenance procedures (Fig. 5).

Interface connection to most LSI-11 series cards is made using flat ribbon cable. For ease of interconnection, the back panel has provisions for mounting bulkhead transition connectors for flat cables (Fig. 4). To allow for the odd cable, the chassis back panel has been designed so that there is a one-inch opening at the top when the chassis is installed with the cover. Additional cables may then be brought out of the enclosure over the top edge of the back panel.

The chassis has been designed to allow rapid maintenance. For example, the chassis boards are mounted using quick-release, snap-in standoffs. Board connectors are either flat cable connectors, or screw lugs on the line-clock generator board and power supply.

SLAC LSI-11 UTILIZATION SURVEY

Forty systems are currently in use at SLAC. The diversity of application and configuration is such that few systems are identical. However, most of the components are interchangeable, even the

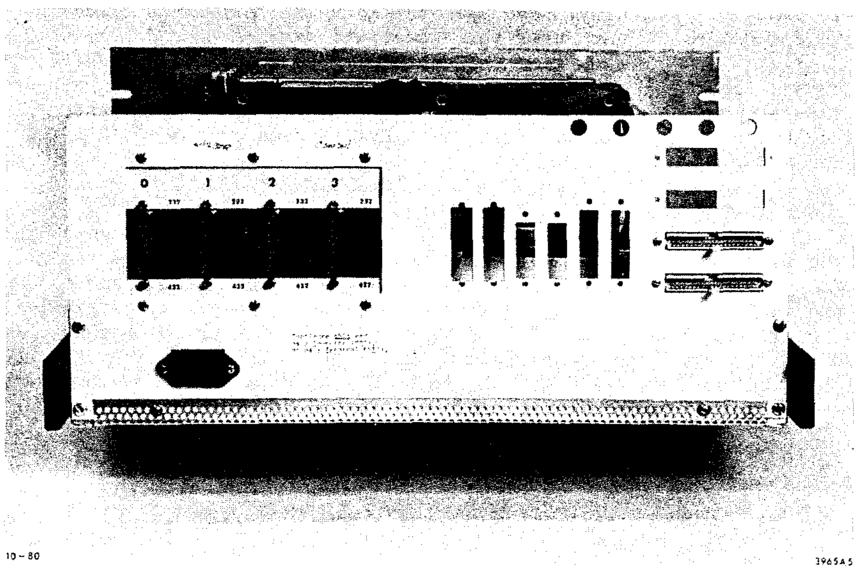

Fig. 4. MK II Chassis, rear view. Note rear panel board mounting and interface cutoffs.

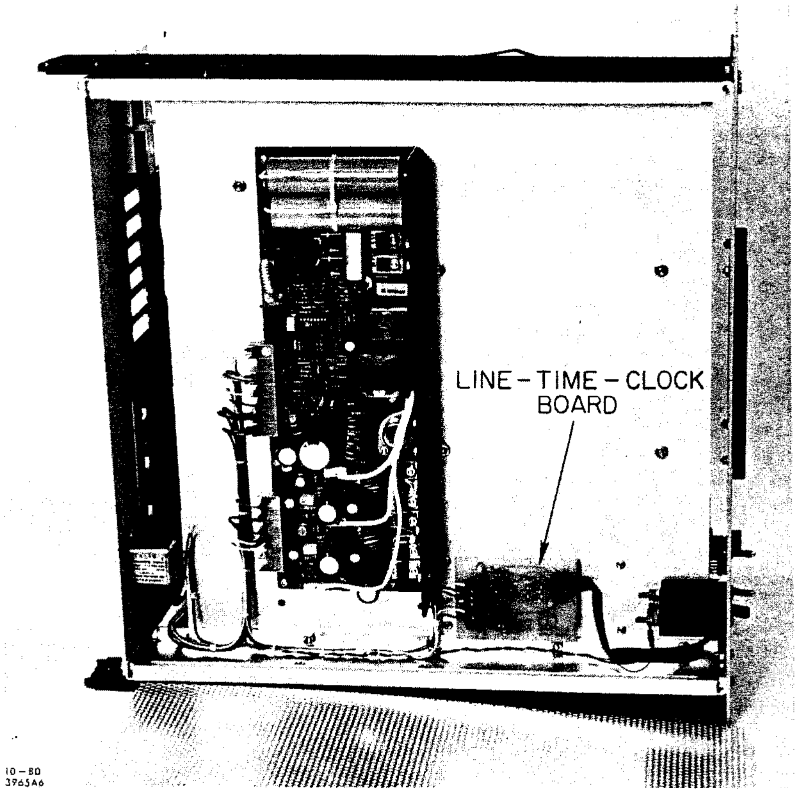

Fig. 5. MK II Chassis, bottom view.

chassis, which simplifies the support of these systems.

Of the 18 systems in use by the research groups, one particular installation[⊕] is of special interest. Five systems are networked on one experiment. One RT-11 based system acts as the multiplexor. It has two terminals and a hard disk attached, and utilizes an LSI-11/23 as the processor. This system includes two DLV11-Js, one being used only as the link to the four other systems. The four satellite systems, each running an ATROPOS program[10] monitor and control detector components, and acquire data from four separate detector systems, all part of the same large experiment installation.

The other 14 research systems are in use by various groups. The systems are used either directly with an active experiment, or in the development and test of detectors and other hardware being constructed for installation.

In addition, the research groups operate four other systems. One is used for hardware development and test. The other three are used for software development of programs which will be run on the experiment support systems noted above.

EIN operates ten systems. Six of these are used by RAI for the development and test of both hardware and software. The other four are used by HEEP for the test and maintenance of CAMAC, NIM, LSI-11 and other hardware supported by the pool.

The eight systems in use for operational support serve a wide variety of functions. These range from the operation of a remote line-printer facility to the steering and control of the particle beam through different experimental areas. Some are used for the monitoring and control of beam polarization. Another controls some of the functions for the injection of the beam into the accelerator. One is being used for the development of new techniques for the control of the accelerator proper. These systems have become necessary tools in improving the beam stability and purity in several different areas.

CONCLUSIONS

The SLAC centralized support structure and the group functions implementing that structure have been described. Also detailed are the evolution of both the support structure and the system chassis which seem to best suit the needs of the SLAC community. The two are closely interrelated allowing each user the system and service needed. At the same time the capability to support a wide diversity of user system and service requirements is maintained. The systems survey presented demonstrates the diversity of systems usage seen at SLAC.

ACKNOWLEDGEMENTS

Over the past 5 years many individuals at SLAC have made significant contributions to the evolution of the hardware design, and the software and maintenance facilities available today. In particular, we would like to thank Leo Paffrath, Michael Stoddard (now with Tymshare, Inc.), Patrick Clancey, Les Cottrell, A. S. Krishnakumar, Ray Larsen, Steve MacKenzie, and Owen Saxton for their contributions and cooperation.

⊕ The DELCO experiment at PEP.

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