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TITLE: AN OVERVIEW OF CTR-DIVISION CONTROL AND DATA ACQUISITION
COMPUTER USAGE AT THE LOS ALAMOS SCIENTIFIC LABORATORY

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__An Overview of CTR-Division Control and Data Acquisition Computer Usage at the Los Alamos Scientific Laboratory.__* G. T. Chandler, K. A. Klare, J. W. Lillberg, and R. W. Wilkins, __Los Alamos Scientific Laboratory__

Computers have become an integral part of the control and data acquisition systems of several different fusion experiments in the CTR Division. These systems must 1) monitor and/or control approximately 200-1000 signals, 2) process from 40 to 250 diagnostic channels with a maximum plasma discharge repetition rate of once every five minutes, and 3) operate in an electrically noisy environment. Small to medium scale minicomputers interfaced to the experiment through CAMAC modules have been used to meet these requirements. System shielding and grounding have been given special consideration. These systems are also used for on-line data analysis and are linked to the local CTR network User Service Center where additional off-line analysis can be performed.

*Work performed under the auspices of the U. S. Department of Energy.

INTRODUCTION

This paper is an overview of the use of computers for data acquisition and control within the Controlled Thermonuclear Research (CTR) Division at the Los Alamos Scientific Laboratory (LASL). It will cover the basic level requirements and general design philosophy, and then trace the expansion of computer usage and evolution of technique over the years and several devices since computers were first used with CTR experiments. Finally, it will describe the design of the ZT-40 control and data acquisition system, which is the latest system and is currently under construction.

The charter of LASL's CTR Division is to explore alternative concepts in the quest to build a magnetically confined plasma fusion device. Work began with the toroidal Z-pinch [illegible] has evolved to the present research on the Reverse Field Pinch (RFP)[1] configuration. The RFP configuration has an axisymmetric toroidal magnetic field geometry consisting of a poloidal field, produced by a toroidal current in the plasma, and a toroidal field whose direction is reversed outside the plasma column. The theta-pinch[2], with a magnetic field geometry which is orthogonal to that of the Z-pinch, has been extensively investigated in both linear and toroidal configurations. Plasma ion temperatures up to 50 million degrees and densities of several times 10^{16} cm^{-3} have been produced in the theta-pinch devices. The experiments use the same type of hardware and pose similar control and data acquisition problems. Table 1 contains a list of parameters relevant to CTR control system design. The experiments are carried out on large pulsed devices, which use spark-gap switched capacitor banks

CAPACITOR BANKS:	$10^5 - 10^7$	JOULES
	$10^4 - 10^6$	VOLTS
	$10^6 - 10^8$	AMPS
PLASMA LIFETIME	$10^{-6} - 10^{-3}$	SECONDS
CONTROL SYSTEM	$10^2 - 10^3$	FUNCTIONS
	10^{-1}	SECOND TIME SCALE
BANK REPETITION RATE	1 - 10	PER HOUR
ELECTRICAL NOISE	LOTS	DAMAGE TO CONTROL COMPONENTS AND INTERFERENCE WITH DATA ACQUISITION
PEOPLE	PHYSICISTS	

LASL CTR COMPUTER ENVIRONMENT

storing up to 10 megajoules of energy at tens of kilovolts, and which produce currents up to 100 megamps . The plasma lifetime is typically in the range of 10 to 1000 microseconds, requiring data acquisition devices which have internal data storage. The control systems must control and/or monitor up to a thousand variables, and cycle several times a second . The devices have repetition rates of 1 to 10 times an hour and are characterized by high electrical noise levels during the plasma discharges. Ground currents and radiated electro-magnetic interference are serious problems. The control system, which may ignore noisy signals for a cycle or two, need only be protected from physical damage. The data acquisition equipment, on the other hand, must be protected from interference which could cause spurious data. Another part of the systems is the people who operate [illegible]. Operators vary widely in their experience with computer software, and the system designer must take this fact into account. The "mal" in operator malfunction [illegible] [illegible]dent.

DESIGN PHILOSOPHY

Software

The goal of software design is to produce programs which are easy to use and easy to maintain. The required operator input should be minimized and the interaction with the operator should occur in the most natural way possible. For example, on the systems described here, [illegible] input is entered through switch panels and thumbwheel switches and visual displays are used extensively. Software maintenance is made easier by modular design and the use of a high level language such as FORTRAN. For the [illegible] a control language has been developed. This language [illegible] a file of command description blocks which are executed by a FORTRAN [illegible] processor. With this approach, the operation of the system may be modified simply by editing the command list; no reprogramming in FORTRAN is required.

Hardware

Hardware has [illegible] top down modular design techniques. A standard interface, the CAMAC[3,4] [illegible] to allow for easy expansion [illegible] controlled by different [illegible] and to take advantage of the wide range of functions [illegible] in the CAMAC format.

A standard signal nomenclature has been devised and is used for both hardware and software. The use of standard nomenclature enhances communication between people of diverse backgrounds.

The electrical noise problems are treated systematically. The devices are characterized as signal sources, the control and data acquisition equipment as receivers, and the [illegible] required to achieve a desired low noise [illegible]. Various techniques —

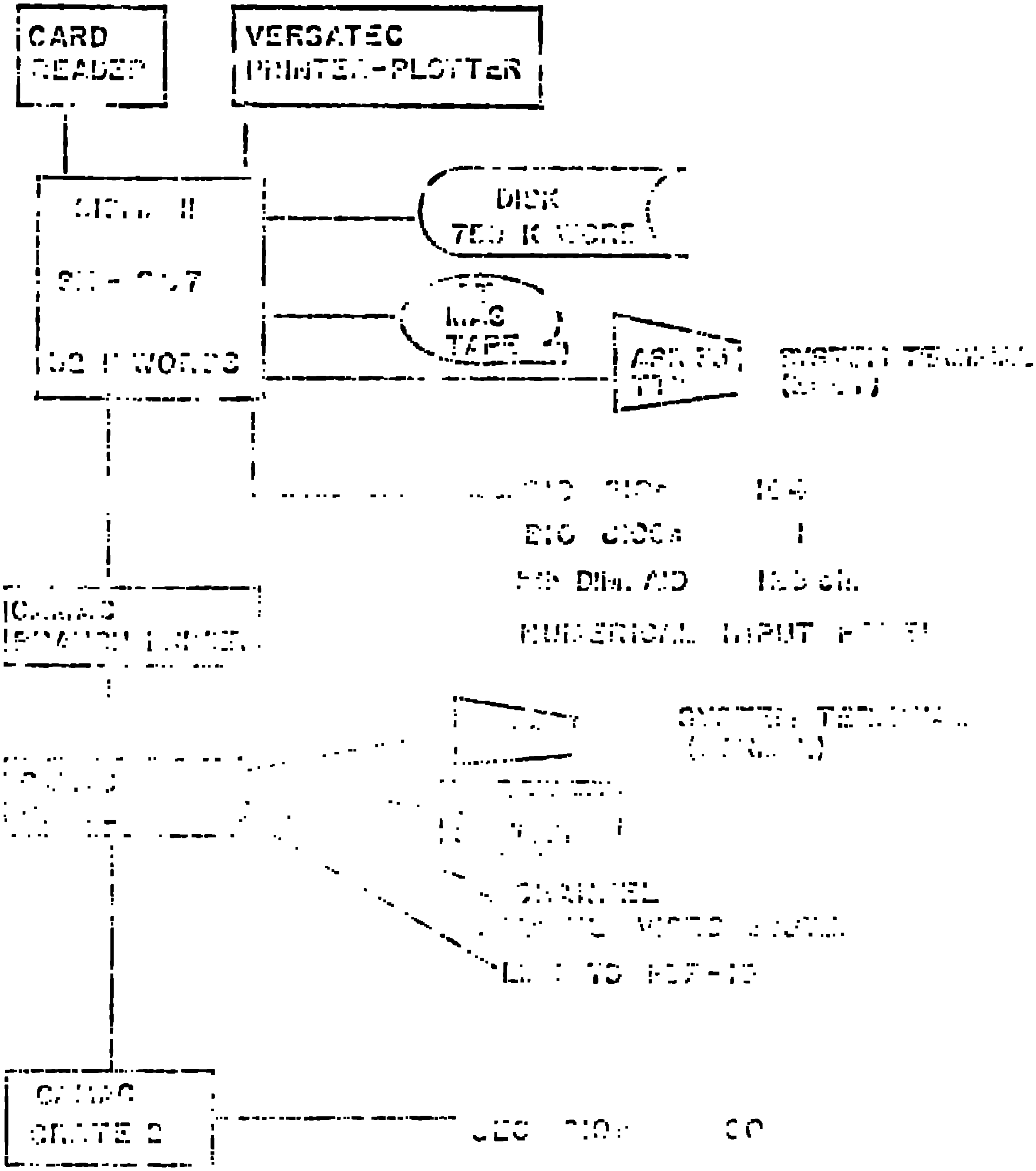
isolation, shielding and transient suppression -- are used to achieve the design goal.

EVOLUTION

Scyllac

The first CTR experiment to use a computer was Scyllac. A Sigma 2 was acquired in 1969 and installed after the device had been designed and was already under construction. The computer was originally used only for data acquisition but later assumed some monitoring and scram/abort functions.

The Scyllac Sigma 2 configuration is shown in Fig. 1. [illegible] data was stored in fast transient digitizers. Slow data such as [illegible] voltages were acquired by a 128 channel analog-to-digital converter (ADC). The operator could control the computer through the numerical input panel. After each plasma discharge the transient recorders were read and the data stored on disk. The operator could call up various data analysis programs and view the results on a multi-channel video display. Additional detailed analysis was done on the User Service Center's DEC-10. The operating system used was the Xerox Real-time Batch Monitor (RBM).



SM-287 (SCYLLAC) SIGMA II

Second Sigma 2

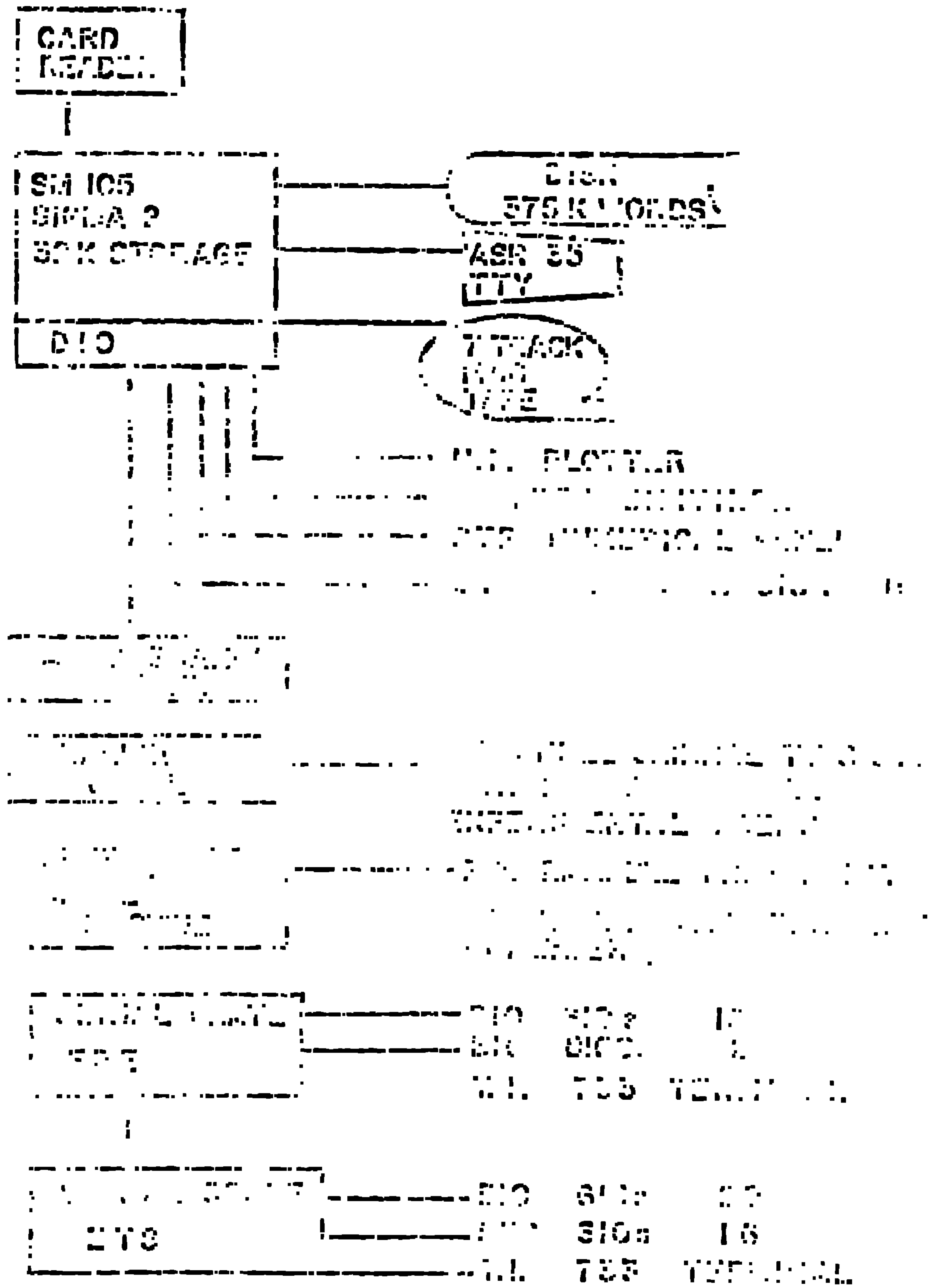
In 1971 a surplus Sigma 2 was acquired. This serves as a data acquisition computer for 4 small experiments. The configuration of this system is shown in Figure 2. Originally all devices were interfaced using Xerox standard interface units. These direct interfaces have been replaced with CAMAC standard interfaces. This computer uses the same Xerox RBM operating system as the Scyllac computer.

Scylla IV-P

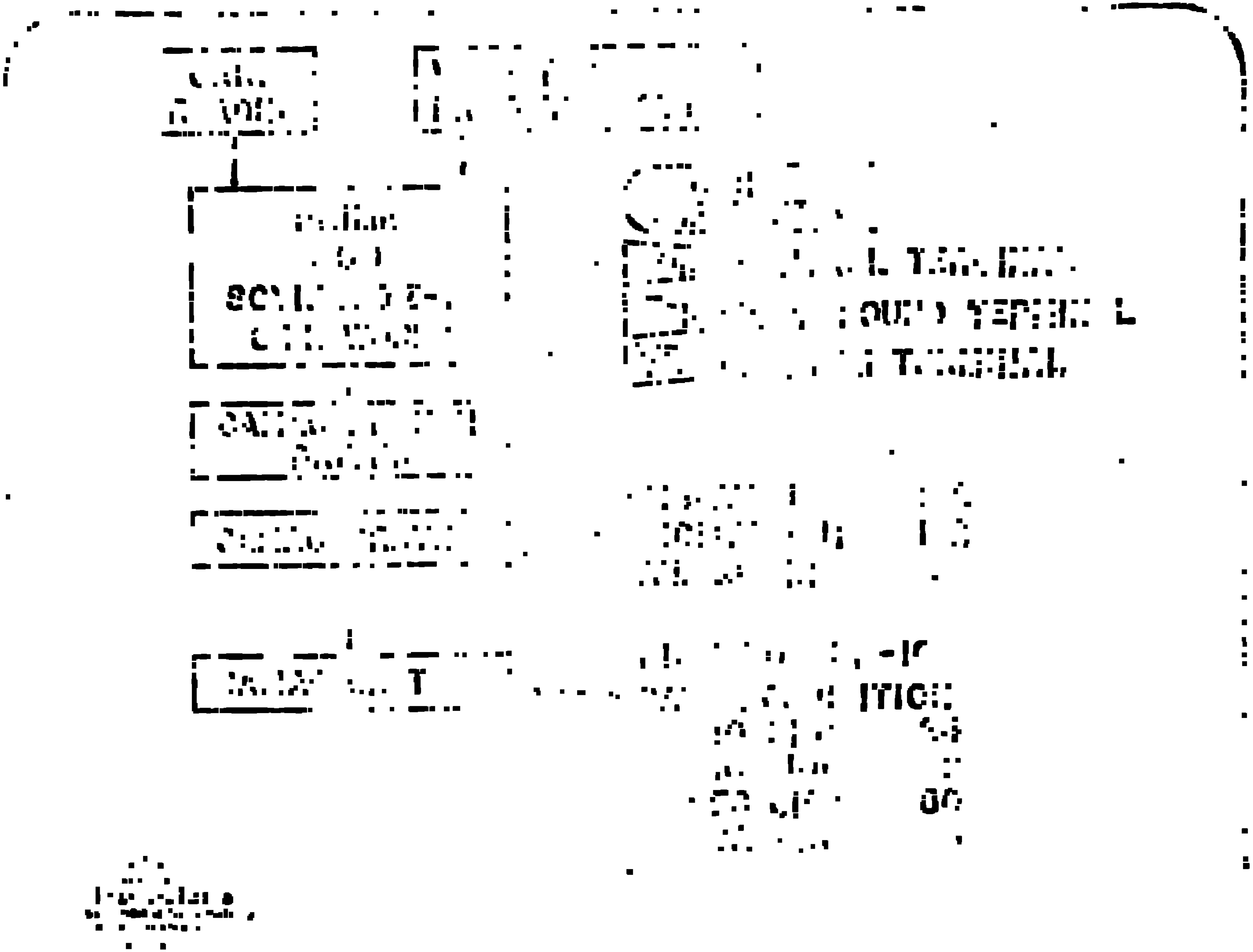
[illegible] construction of Scylla IV-P, a [illegible] meter linear theta pinch[illegible], was begun in 1975. This was the first computer control and data acquisition system designed as an integral [illegible] physics device at LASL. The computer chosen was a Prime [illegible]. Figure [illegible] diagrams the configuration. All the interfaces are through [illegible] standards. [illegible] Prime's real-time operating system (RTOS) which is a multi-foreground, single background operating system. The control language approach was developed on this system. All of the control and data acquisition tasks operate in the foreground. The background, which has a 64K word virtual address space, is used for on-line data analysis.

LATEST DESIGN

ZT-40, a large [illegible] pinch, is currently under construction. It is the most complex device built in CTR at LASL in



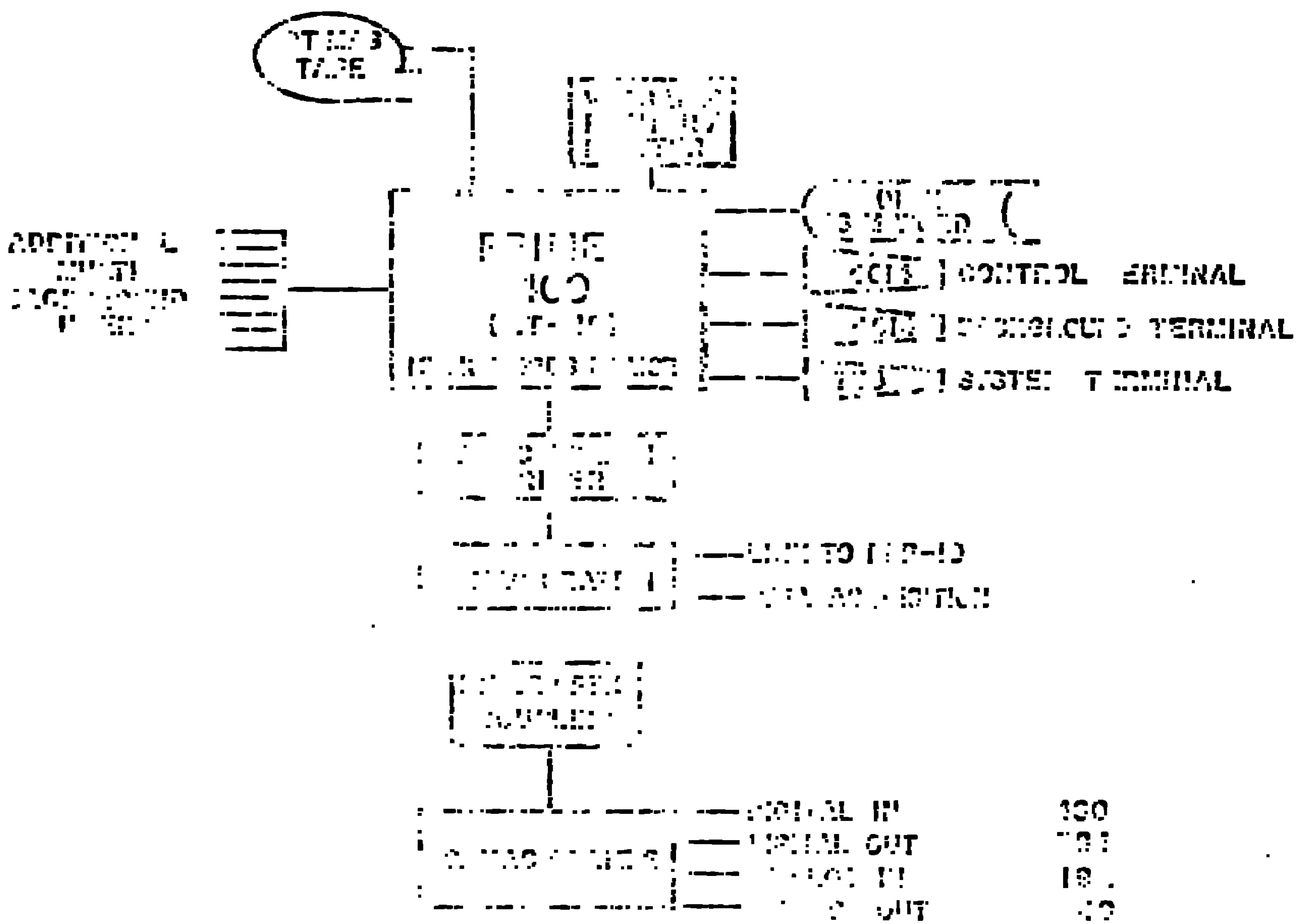
SM 105 (SECOND) SIGMA II CONFIGURATION



[illegible] number [illegible] control functions which must be implemented, and the sensitivity to electrical noise of the data acquisition equipment. A [illegible] 750 with [illegible] [illegible] virtual memory operating [illegible] the control and data acquisition computer. This [illegible] in Figure 4. All interfaces to the [illegible] acquisition equipment [illegible] via a [illegible].

[illegible] or periodic [illegible] to a [illegible] basis. A [illegible] This routine is used [illegible] code in memory [illegible] is in operation. A set of software queues [illegible] for inter-process [illegible] has been [illegible] to allow [illegible] to execute at a priority higher than that of the [illegible].

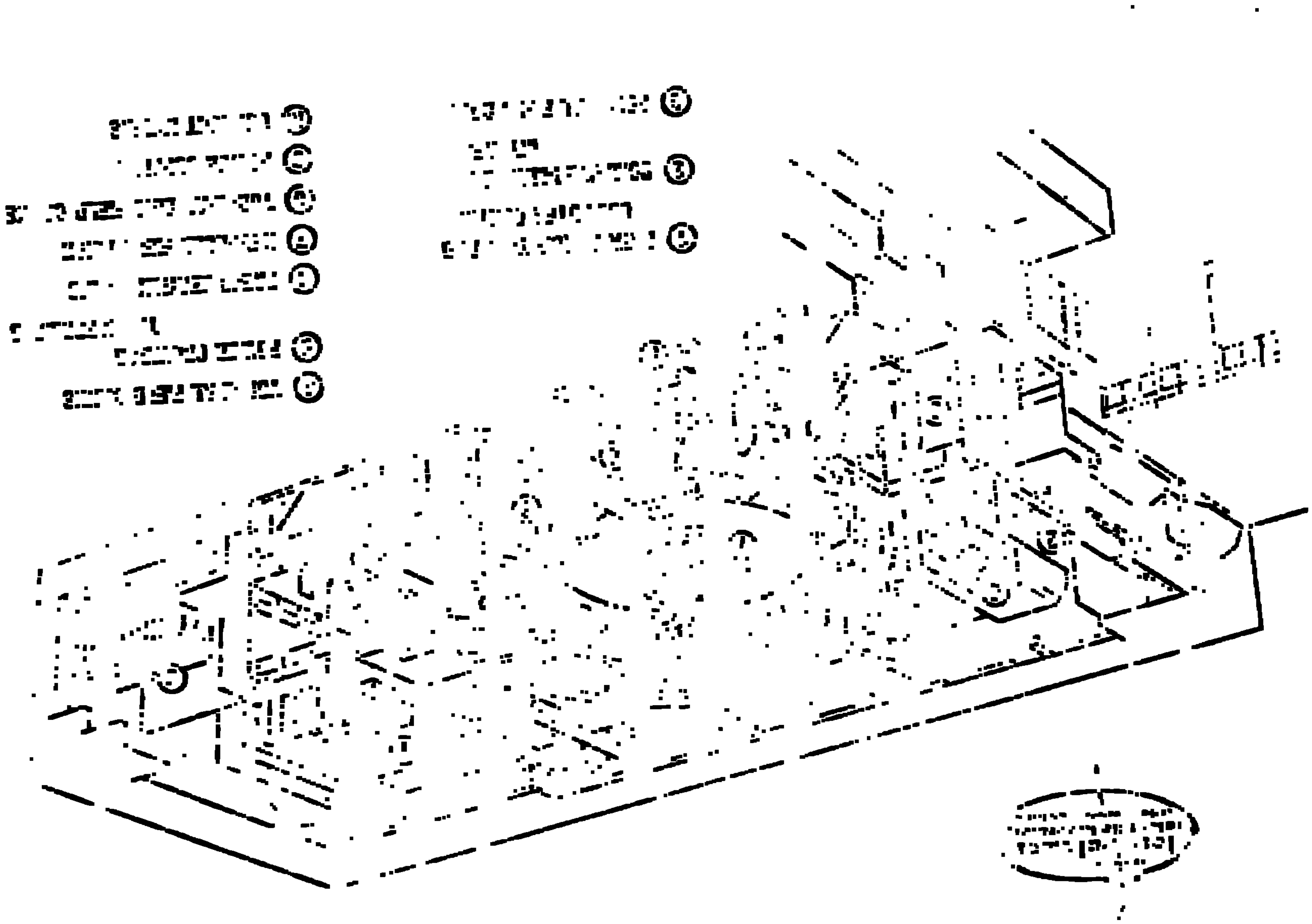
The control software is modeled after that of [illegible] although the [illegible] is quite [illegible] because of the difference in operating [illegible]. Four processes are involved: 1) a monitor process


CONTROL
TERMINAL

which carries out all I/O operations with ZT-40 and provides current status information, 2) a CAMAC interrupt handler, 3) a control process, which is the control language processor and operator interface, and 4) a sequential processor for data acquisition programs. Since PRIMOS IV is a time-sharing system, program development, data analysis and diagnostic development can be carried out concurrently with device operation.

Figure [illegible] of the area in which ZT-40 is being built. The [illegible] center is the plasma vessel with its associated conductors and [illegible] torus. Diagnostic equipment will be located on the platform around the torus. The shield room containing the computer, data acquisition equipment and timing pulse generators is located at [illegible] end of the area. A control [illegible], containing the [illegible] and interface circuitry is located in relay racks at the opposite end of the area. The charging system power supplies are in a [illegible] below the [illegible]. The main capacitor banks are built in [illegible] sections around the torus. Several auxiliary banks are located in [illegible] corners of the area.

The noise susceptibility of the plasma diagnostics has necessitated the design of an elaborate star type grounding and shield system [illegible] a point near the feedplate. Conductors carry [illegible] [illegible]. The steel structural framework was built in several sections, which are electrically isolated from each other and from the [illegible], including the reinforcing rods in the concrete floor. This insures that ground

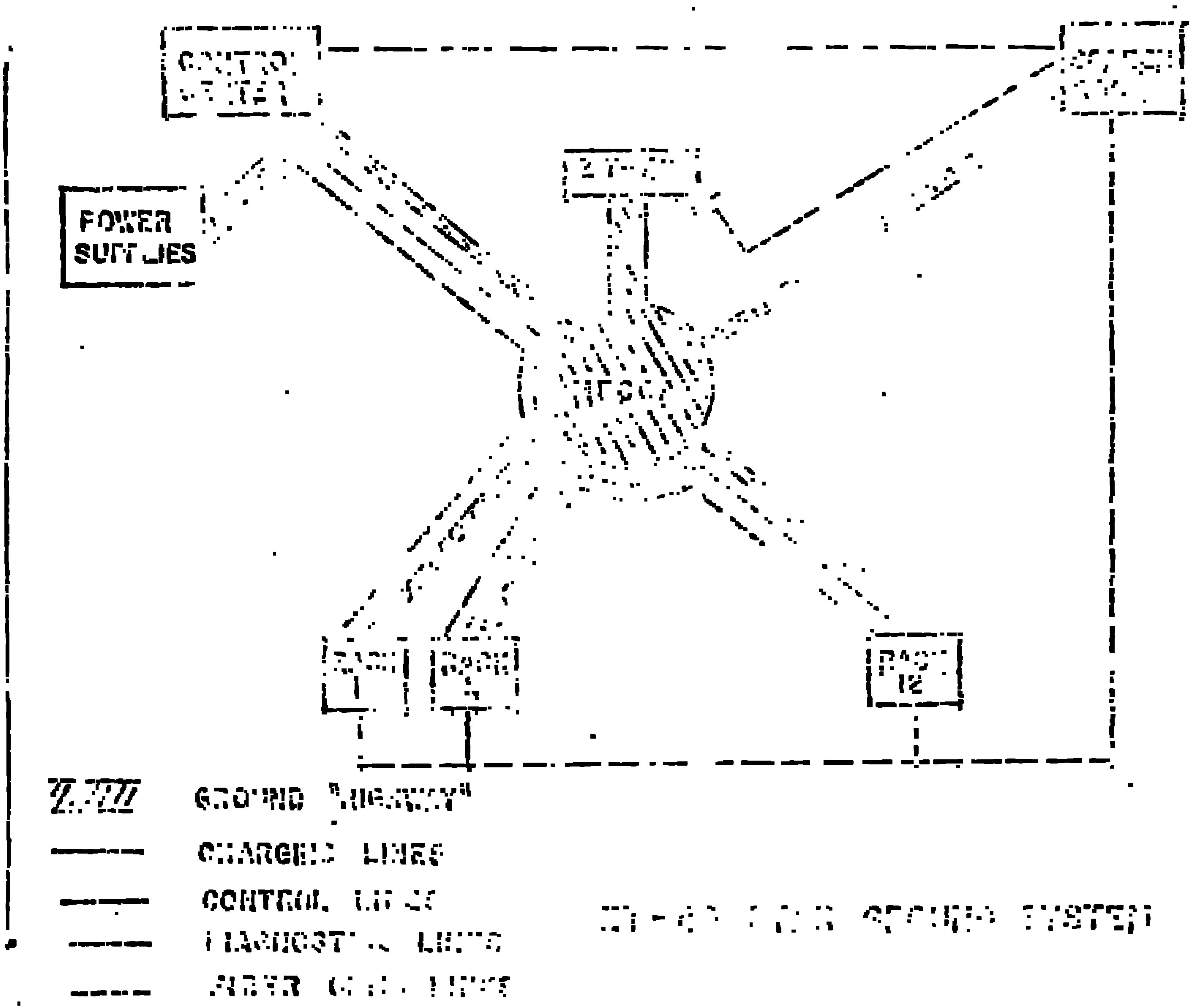


currents are flowing only in the ground-ways intentionally established. Ground loop areas are minimized by running all cables between various parts of the experiment along the ground-w[illegible] system. Ground loop problems in the control wiring and the timing-pulse cables have been minimized by the use of fiber optics.

The bit-serial highway is carried between the control center and the shield room on 18 optical fibers. These fiber optic links were designed and built in-house. The circuitry in the control center, while not as sensitive to noise as the data acquisition equipment, still needs to be protected against physical damage by transients which could be as high as several hundred volts. These voltages are caused by changes in ground potential around the [illegible] during plasma discharges. Transient suppression [illegible] and optical isolation [illegible] operate solenoid driven air valves which are connected to the device through non-conductive plastic [illegible]. The [illegible] from switches located around the device which are isolated from ground. Likewise, the [illegible] currents, all [illegible] power supplies, are isolated at their destination. Only the analog inputs are referenced to the local ground at their source.

Figure 6 illustrates the techniques employed in the [illegible] cabling. Several junction [illegible] the [illegible]

*H-" opti-iso gates [illegible] digital [illegible] and optically coupled analog isolators from Burr-Brown [illegible]

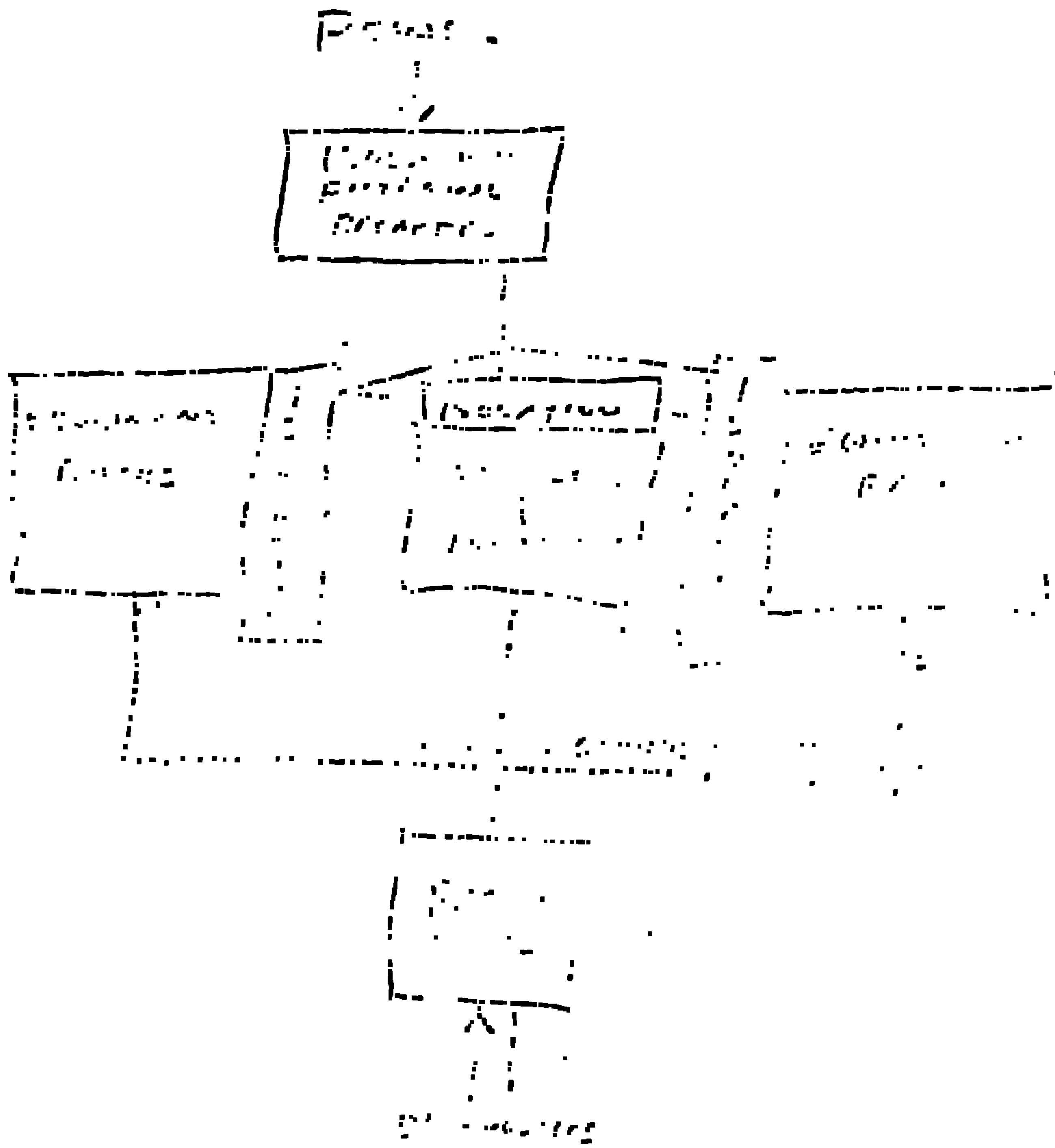


GROUND SYSTEM

plation near the torus. Coaxial cables from these junction boxes are carried in 20 two inch copper pipes to the shield room. These pipes are in turn encased in a 1/8 inch steel box. The purpose of this arrangement is two fold. The copper pipes, tied to the cables at each end, help to reduce crosstalk. Crosstalk is further reduced by threading each cable several times through a stack of ferrite cores inside the shield room. The steel box, also connected to the cables at each end, increases the diffusion time for current induced in the ground loop formed by the conduit array and shield room, and coupled by [illegible].

Figure 7 is a diagram of the layout of the equipment in the shield room which also has a star [illegible], control terminal and peripherals are located in the center of the room. Relay racks are placed around the periphery of the room. Signal cables are [illegible] between [illegible] equipment [illegible] plan [illegible] are minimized by [illegible] and by providing a single connection between [illegible] and the [illegible] plane. Power is distributed throughout the room by a separate wireway structure. Twisted pair wiring is used to further reduce [illegible] coupling. Isolation [illegible] at each equipment location break the ground loop. [illegible] are housed in three layer magnetic shields to reduce the [illegible].

The [illegible] enclosure is a [illegible] shield room, 22 feet by 25 feet. The orginal design was modified by replacing the copper layers with



silicon transformer steel. This extended the low frequency attenuation to cover the expected peak in the ZT-40 power spectrum which occurs at 300 Hz. AC power for the room is supplied by a 75 KVA 3 phase isolation transformer. This power is then filtered before and after entering the room.

CONCLUSION

The use of top-down, modular design techniques in both software [illegible] hardware increases system [illegible] [illegible] maintenance effort. [illegible] hard interface is [illegible] The time [illegible] spent [illegible] designing a system [illegible] with careful consideration of power and ground [illegible] physical, prior to the [illegible] [illegible] was divi[illegible]. This [illegible] of [illegible] and the transfer [illegible] different manufacture.

REFERENCES

1. D.A. Bodin and E.E. Keen, Reports on Progress in Physics, 40, 1415:1977.

2. J.P. Freidberg, et.al., Review of Linear Theta Pinch (LTP) Concepts, [illegible]-77-[illegible]61.

3. S[illegible] al Highway Interface System (S[illegible]C), IEEE Std 59[illegible] 1976.

4. Parallel [illegible] (C[illegible]), IEEE Std 595-1976.

5. J.W. [illegible], et.al., Proceedings of the [illegible] Symposium on Engineering Problems of Fusion [illegible] (1975) [illegible] 1050-1054, IEEE Pub. No. 75CH1097-5-NPS.