Feasibility Study of Common Electronic Equipment For Shuttle Sortie Experiment Payloads

Final Report
BSR 4142
June 1974

Ann Arbor, Michigan

Bendix **Aerospace Systems Division**

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Bendix Aerospace Systems Division

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SECTION 1

INTRODUCTION

NASA has been investigating approaches to reduce costs of flight experiments. These costs have been high because of the need for low weight and power and for operation in a hostile environment. New flight assignments have usually required new electronic developments. The Space Shuttle with its large payload carrying ability and relatively mild launch and flight environment will allow the use of high quality commercial electronics for the first time. If the commercial electronics are standard and modular so that the modules are compatible, expandable, flexible, and interchangeable, then the modules can permit multiple payload usage and rapid payload turnaround. The NIM and CAMAC standards offer the above features for the Space Shuttle; and the study, described in this report, covers the application of NIM-CAMAC modular electronics to several potential Space Shuttle Sortie Payloads and the feasibility of whether the standards meet the Space Shuttle environment.

NIM-CAMAC standards were developed for ground-based laboratory nuclear instrumentation equipment in order to reduce the need for one-of-a-kind electronics that made nuclear instrumentation a high cost item for experiments. Use of NIM-CAMAC standards has been extended to astronomy, medical electronics, and industrial process control. There are many manufacturers in the United States and Europe who manufacture electronic modules to NIM-CAMAC standards. Demand for the modules is such that competition has resulted in making the modules economical and reliable and assuring a continued development of new modules to expand the electronic functions available to an experimenter.

NIM standards were written in 1964 by the United States AEC Committee on Nuclear Instrument Modules to assure mechanical and electrical interchangeability of transistorized modular instruments. The standards do not specify data acquisition modes. CAMAC modular instrumentation system standards for data handling were promulgated in 1969 by the ESONE Committee of European Laboratories in cooperation with the United States AEC NIM Committee, who subsequently endorsed them. The standards specify a system suitable for digital data acquisition from, and control of, plug-in modules along common data highways (Dataways), using a digital controller or computer.

NIM and CAMAC standards are in use by scientists in the United States in universities and national laboratories. Visits were made to the NSF (National Science Foundation) National Accelerator Lab at Batavia, Illinois, to the NSF Kitt

Peak National Observatory at Tucson, Arizona, and to the AEC Los Alamos Meson Facility at Los Alamos, New Mexico, to see how they have managed their NIC-CAMAC instrumentation systems. All three had similar management approaches. They all maintained a pool of NIM-CAMAC equipment from which an experimenter could borrow for the duration of his experiment. Collectively these three laboratories simultaneously support about 40 experiments in high energy physics and astronomy with a $7 million pool of electronics. The size and complexity of these experiments are similar to those proposed for Space Shuttle Sortie Missions.

A comparison of weight and power for the NIM-CAMAC electronics compared to special designed flight hardware was made for the two Skylab earth resources payloads (13-band orbital multispectral scanner, S-192; and Microwave Radar, S-193) as data were available for the Skylab version. The NIM-CAMAC electronics for S-192 weighed 373 kg (821 lb) and required 870 watts (W) compared to 200 kg (441 lb) and 366 W for Skylab; and for S-193 the NIM-CAMAC electronics weighed 300 kg (660 lb) and required 660 W compared to 168 kg (370 lb) and 400 W for Skylab. The weight is not likely to be reduced by the manufacturers, but the power has been reduced in some cases. The National Accelerator Laboratory has specified a low power requirement on new modules and the manufacturers have responded with lower power designs. The power requirement on Shuttle could be further reduced by redesigning the NIM-CAMAC power supplies for the 28 V ± 4 V Shuttle electrical bus voltage. All power converters consume power; converting 28 V to 110 V, 60 Hz, then to NIM-CAMAC voltages is inefficient.

Two approaches for housing experiment electronics on the Shuttle were considered: (1) in the habitable crew compartment and (2) in pressurized containers mounted on the pallet. Electronics in the crew compartment must not outgas contaminants. The computer, branch driver, keyboard, and display would be in this compartment. PVC and other plastics and finishes that outgas cannot be used. Since this equipment would be required on most Sortie flights, the equipment could be built to NASA flight hardware specifications without a major cost impact per experiment. Equipment housed in the pallet container will not have any special outgassing requirements. This equipment could either be furnished by NASA or provided by the experimenter from commercial vendors or his own fabrication of special NIM-CAMAC modules.

Static and dynamic analyses of NIM-CAMAC equipment show that it can be made compatible with the Space Shuttle environment. Bins and crates will require mounting on rails rather than cantilevering on a rack. Forced air cooling will have to be added for NIM bins. Both NIM and CAMAC compartments will require heat exchangers of approximately 150 W of cooling per MIN-bin and 450 W of cooling per CAMAC crate. Other mechanical changes to the NIM-CAMAC are:

- Fixing (Thumb) Screws - CAMAC modules are fabricated with only one fixing screw at the bottom of the module front panel. Manufacturers of printed circuit board connectors agree that for flight application of edge-board connectors, it would be necessary to include a second fixing screw at the top of the front panel similar to NIM modules. Most CAMAC crates have the required hole pattern in the top crate rail so that only the modules, not the crates, require modification.

- Module Guide - The clearance between the module guide in the CAMAC crate and the module runner is 0.7 to 1.0 mm. This clearance permits considerable free movement of the metal-to-metal surfaces of the crate guide and module runner and would present a problem in vibration. A liner of resilient material installed in the guide would dampen the vibration.

- Threaded Fasteners - The NIM-CAMAC standards do not control the application of threaded fasteners. Some manufacturers use threaded inserts for fastening the aluminum, but the practice is not uniform. For flight applications, use of threaded fasteners should be in accordance with MIL-STD-454, requirement 12. In areas where disassembly is infrequent or not required, use of self-locking inserts should be imposed.

The connectors used in NIM and CAMAC equipment are prohibited by current NASA specifications for use in flight hardware. Acceptance will have to be gained for their use. The requirement that identical connectors on adjacent cables shall not be used is contrary to the modular concept. The requirement has been imposed to prevent improper connections. Laboratory practice is to wire tag the conductors to assist uncoupling and recoupling connectors to the proper receptacle.

The NIM connector and the CAMAC Dataway connector are not flight qualified. Similar connectors have been flown, and these connectors should be flight qualified or a substitute connector developed for the Shuttle environment. The fact that equipment manufacturers are not extending the requirements of the NIM-CAMAC standards to suppliers of connectors presents another problem.

The CAMAC modules use an edge-board connector, which is prohibited in flight hardware. This connector might be accepted if it can be shown that it will pass a qualification test conducted according to Paragraph 4.5 of Specification MIL-C-21097C modified to simulate the Space Shuttle environment.

A disadvantage of the edge-board connector is that during insertion and withdrawal the edge-board conductors short the connector, causing a burnout of board components. Laboratory practice is to turn off the crate power whenever a module is changed. It may be possible to interlock the crate modules to automatically shut off the power until the module is firmly in place.

Failure to qualify edge-board connectors for flight application would require modification of equipment to use a two-part printed circuit board connector. Two-part printed circuit card connectors are available that could be interchanged with the edge-board connectors without altering the crate configuration.

CAMAC grounding combines signal and power grounds. This approach is not approved for flight hardware because of ground loops. Optical isolators have been developed for CAMAC to overcome ground loop problems, and this approach needs to be qualified or approved for the Space Shuttle.

The CAMAC standards are based on parallel data entry and parallel data highways. The parallel system has faster access times, but it does lead to cabling problems and interface problems with the Shuttle flight data computer and telemetry. The ESONE and AEC NIM Committee have recently endorsed a serial system organization (TID-26488). Both bit serial over a single transmission line and byte serial over eight lines are approved. Serial crate controllers are not yet available commercially and were not considered in this study. When they do become available, they should be considered for reducing the cabling through hermetic feedthroughs and for communication with the Shuttle flight data computer and the Shuttle telemetry system.

The launch and landing environment for Shuttle has not been firmly established. Early estimates of a mild environment may turn out to be wrong. The modifications required to meet a rugged environment may exceed what is practical to impose on commercial equipment. NIM-CAMAC could still be implemented by NASA procuring flight versions of the NIM-CAMAC equipment and reserving the use of commercial equipment for experiment development.

SECTION 2

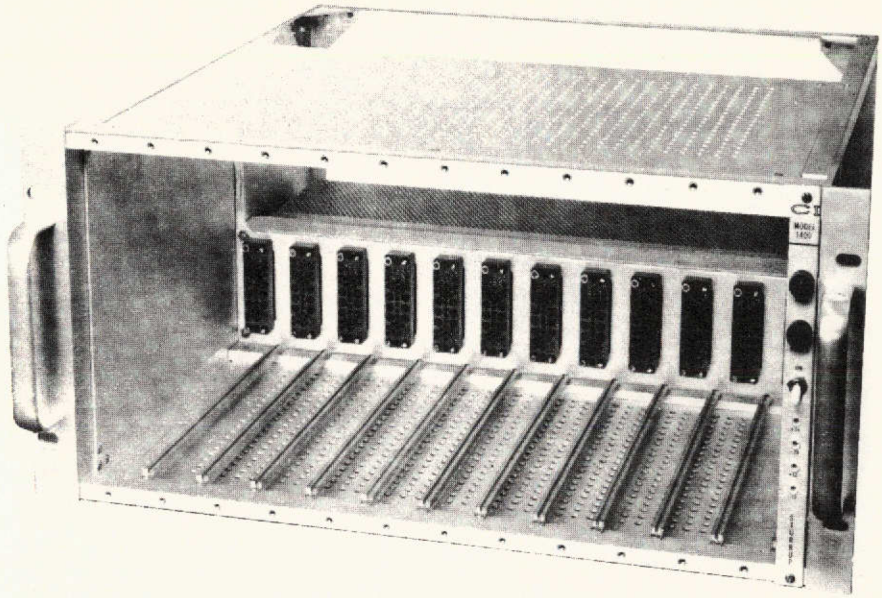
THE NIM-CAMAC CONCEPT

NIM and CAMAC are standards for ground-based laboratory nuclear instrumentation equipment. NIM standards were written in 1964 by the United States AEC Committee on Nuclear Instrument Modules to assure mechanical and electrical interchangeability of transistorized modular instruments. The NIM system is now widely used internationally by laboratories and industry and has been adapted as integrated circuits have displaced discrete components. The standards do not specify data acquisition methods. CAMAC modular instrumentation system standards for data handling were promulgated in 1969 by the ESONE Committee of European Laboratories in cooperation with the United States AEC NIM Committee, who subsequently endorsed them. The standards specify a system suitable for digital data acquisition from, and control of, plug-in modules along common data highways (Dataways), using a digital controller or computer. The form of the system and the attractive module size stem from integrated circuit technology. The electrical specifications require TTL compatibility.

2.1 NUCLEAR INSTRUMENTATION MODULES (NIM)

The NIM standards specify mechanical and electrical interface characteristics of NIM functional modules and the rack-mounting cabinets which contain and power the modules. The rack-mounting cabinets are designated "NIM bins." Figure 2-1 shows a typical NIM bin and power supply. The bin accommodates 12 single-width modules or any combination equal to 12 total module widths. Wiring is provided for ±24 volts (V), ±12 V, ±6 V, clean and dirty ground, and 115 Vac. The ±6 V is optional. Total power available on ±12, ±24 Vdc is 72 W and on ±6, ±12, ±24 Vdc is 100 W (400-W input). The control panel shown at the right edge of the bin includes an On-Off switch, pilot lamp, and temperature warning lamp that indicates temperatures approaching the design limit. The bins mount in standard EIA 19-in. racks and are available in both 222 mm (8 3/4 in.) and 133 mm (5 1/4 in.) panel heights to accommodate standard NIM modules. The size of a bin with ±12, ±24 Vdc power supply is 222 mm (8 3/4 in.) H x 483 mm (19 in.) W x 406 mm (16 in.) D and weighs 11.5 kg (26 lb). The size of a bin with ±6, ±12, ±24 Vdc power supply is 222 mm H x 483 mm Wx 457 mm D and weighs 14 kg (32 lb).

A wide variety of NIM modules are available for implementing nuclear instrumentation laboratory systems. Table 2-1 lists representative modules available. Following the table is a technical specification sheet for a typical NIM module.



12064-1

Figure 2-1 Typical NIM Bin with Power Supply

The specification shows typical applications of this module interconnected with other NIM modules. NIM modules are interconnected and connected to sensors and other non-NIM equipment through front-panel connectors.

Table 2-1

Representative NIM Modules

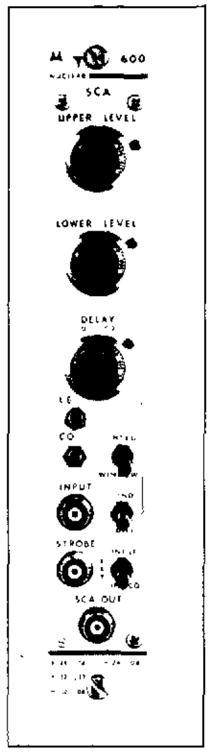
	NIM Width
Reference Pulser	2
Random Noise Pulser	1
Linear Amplifier	3
DDL Amplifier	1
DC Restorer	1
RC Amplifier	1
Spectroscopy Amplifier	1
Spectroscopy Amplifier	2
Spectroscopy Amplifier	1
Zero Strobe	1
Single Channel Analyzer	2
Integral Discriminator	1
Timing SCA	2
Fast Coincidence	2
Coincidence	1
Dual Linear Gate	2
Linear Gate	1
Logic Shaper and Delay	2
Dual Linear Delay	1
Biased Amplifier and Pulse Stretcher	2
Biased Amplifier	1
Stretcher	1
Summing Amplifier	2
Inverting Amplifier	1
Linear Ratemeter	2
Twin Digital Stabilizer	3
Stabilization Pulser	1
Digital Stabilizer	2
Scaler	2
Scaler, Serial BCD	2
Scaler, Preset, Parallel BCD	3
Blind Scaler, Serial BCD	1
Blind Scaler Display	2
Data Input Modules	3
Serial to Serial/Parallel Buffer	2
Data System Multiplexer	3
Magnetic Tape Print Control	2
Paper Tape Print Control	2
Teletype Print Control	2
Scanner/Printer, Serial BCD	4
Blind Timer	1
Timer/Scaler, Line Frequency, Serial BCD	2
Timer/Scaler, Crystal Time Base	2
Timer, Crystal Time Base, Parallel BCD	3
Clock, Time of the Year, Serial BCD	2
Clock, Time of the Day, Serial BCD	2

TECHNICAL SPECIFICATIONS Model 600 Series

Model 600 Timing Analyzer

MODEL 600 TIMING ANALYZER

- *Internal Leading Edge or Crossover Discrimination*
- *Pulse Pair Resolution 600 Nsec.*
- *Stacked or Independent Analyzer Modes*
- *DC Restored Input*



DESCRIPTION

The Mech-Tronics Nuclear Corporation Model 600 Timing Analyzer is a single width AEC Module that combines the functions of a differential pulse height analyzer and a multimode integral discriminator.

In the pulse analyzer mode the Model 600 will generate a logic pulse output for each accepted input pulse whenever the signal amplitude falls within the range defined by front panel control settings.

If operated in the integral discriminator mode a logic output will be generated for each input signal above the lower level (baseline) control setting.

The inherent flexibility of the Model 600 Timing Analyzer permits its operation in any one of nine modes through switch selectable programming of front panel controls. This flexibility is provided by the timing options available in each of the three basic modes. The user, upon determining whether his needs are for integral discrimination, stacked or independent window, can then select internal leading edge, crossover, or external timing. A variable delay is provided to set the time interval between time reference and generation of the logic output.

COMPATIBLE EQUIPMENT

The Model 600 Timing Analyzer is fully compatible with all Mech-Tronics required Nuclear amplifiers, logic modules, scalers and ratemeters. All required power levels are available from any of the Mech-Tronics' instrument bins and power supplies.

SPECIFICATIONS

Linear Signal Input:	
Range:	200 mv - 10.2 volts; 20 volts max.
Polarity:	Positive monopolar or bipolar
Width:	200 nsec. minimum
Impedance:	1 K ohms

Mech-Tronics NUCLEAR Division of Sansteel Inc

1723 N. 25th Ave., Melrose Park, Illinois 60160
Phone: 312-344-2212

600 - 2

SPECIFICATIONS (cont.)

Ext. Strobe Input:

Amplitude:	Positive 3 volts to 50 volts
Rise Time:	100 nsec. maximum
Width:	80 nsec. minimum
Impedance:	1.5 K ohms

SCA Output:

Amplitude:	Positive 6 volts direct coupled gnd. referenced
Width:	200 nsec. fixed
Rise Time:	Less than 50 nsec.
Impedance:	50 ohms

Fast Output:

Amplitude:	Negative 0.7 volts when terminated in 50 ohms
Rise Time:	Less than 5 nsec.
Width:	15 nsec. maximum
Impedance:	50 ohms

Performance:

Lower Level Bias Linearity:	0.25% of full scale
Upper Level Bias Linearity:	0.25% of full scale
Window Width Linearity:	0.25% of full scale
Bias Stability:	1Mv/°C

Crossover Walk for 0.8 usec. RC double differentiated active integrated pulse as obtainable from the Mech-Tronics Nuclear Model 501 Amplififer. 8 nsec. for 50:1 dynamic range (200 Mv to 10 volts).

Leading edge timing walk for 1.5 usec. single RC Differentiated pulse with Rise Time of 170 nsec.

Dynamic Range	Output Walk
2:1	10 nsec.
5:1	20 nsec.
10:1	40 nsec.
20:1	60 nsec.
50:1	100 nsec.

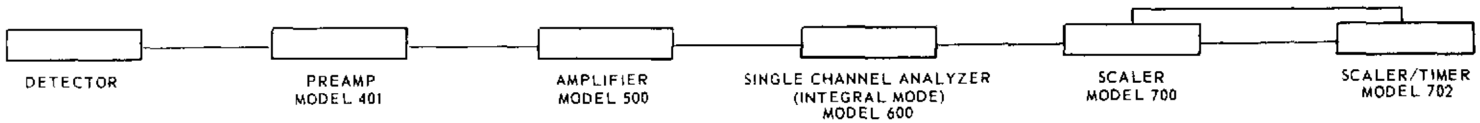
Strobe Delay Stability:	±0.5 nsec./°C at 1200 nsec. delay
Pulse Pair Resolution:	600 nsec.

Controls:

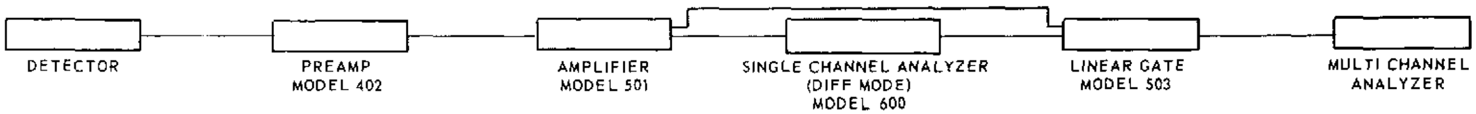
Upper Level:	Front panel ten-turn pot with duo dial 0.2 to 10.2 volts in window/independent mode and 0 to 2 volts in window/diff mode.
Lower Level:	Front panel ten-turn pot with duo dial 0.2 to 10.2 volts.
Strobe Delay:	Front panel ten-turn pot with duo dial permits delay from 200 to 1200 nsec. of internal or external SCA strobe.

TYPICAL APPLICATIONS

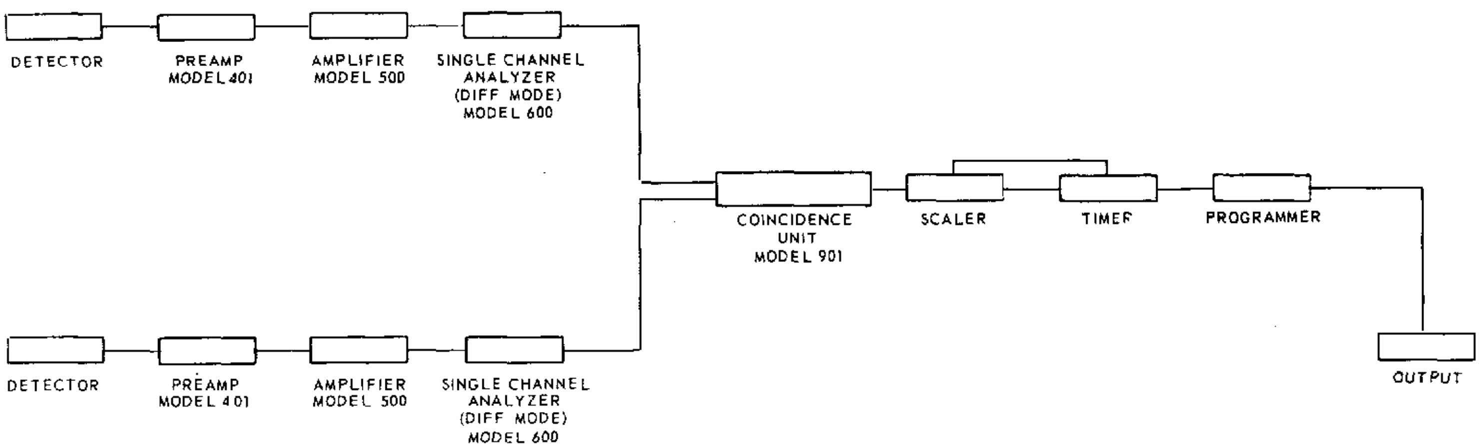
INTEGRAL COUNTING



SINGLE CHANNEL/LINEAR GATING – PULSE HEIGHT ANALYSIS



COINCIDENCE COUNTING



600-3

SPECIFICATIONS (cont.)

L. E.	Front panel screwdriver adjust permits 0 to 1 volt range of adjustment of internal timing discriminator threshold. To set leading edge trigger above noise level.
C. O.	Front panel screwdriver adjust permits adjustment of crossover reset of internal timing discriminator.
Integ/window:	Front panel toggle switch which permits integral or window (SCA) operation
Ind/Diff.	Front panel toggle switch which permits independent UL and LL control of window in IND position or stacked operation in the Diff. mode where the UL pot has a 20% of full scale range (2 volts).
Strobe Int LE: Ext: Int Co:	Front panel 3 pos. toggle switch permits selection of internal leading edge, internal crossover or external strobe timing.
Connectors	
SCA Output:	Front and rear panel BNC UG1094A/U
SCA Input:	Front and rear panel BNC UG1094A/U
Strobe Input:	Front panel BNC UG1094A/U
Fast Neg. Output:	Rear panel BNC UG1094A/U
Power Requirements:	+24 volts @ 80 ma −12 volts @ 40 ma +12 volts @ 170 ma −24 volts @ 80 ma
Ordering Information:	
Shipping Weight:	5 lbs.
Size:	Single Width AEC Module per TID-20893
Ordering Stock No.	000600-00

2.2 CAMAC*

The CAMAC standard, like NIM, specifies the mechanical and electrical interface characteristics of CAMAC functional modules and the rack-mounting cabinets which contain and power the modules. In addition, however, the CAMAC standard specifies the characteristics of a digital data transfer "highway" through which the modules are controlled by a digital controller or computer and through which inter-module and computer data transfers take place.

A typical CAMAC module is shown in Figure 2-2. The front panel is 222 mm (8 3/4 in.) high and 17.0 mm (0.7 in.) wide (half as wide as a NIM module). As with NIM systems, the modules can come in any multiple of the single width. The single-width module accommodates a single board with soldered-in integrated circuits; a double-width module can take two such boards or one board with wire wrap sockets for the integrated circuits.

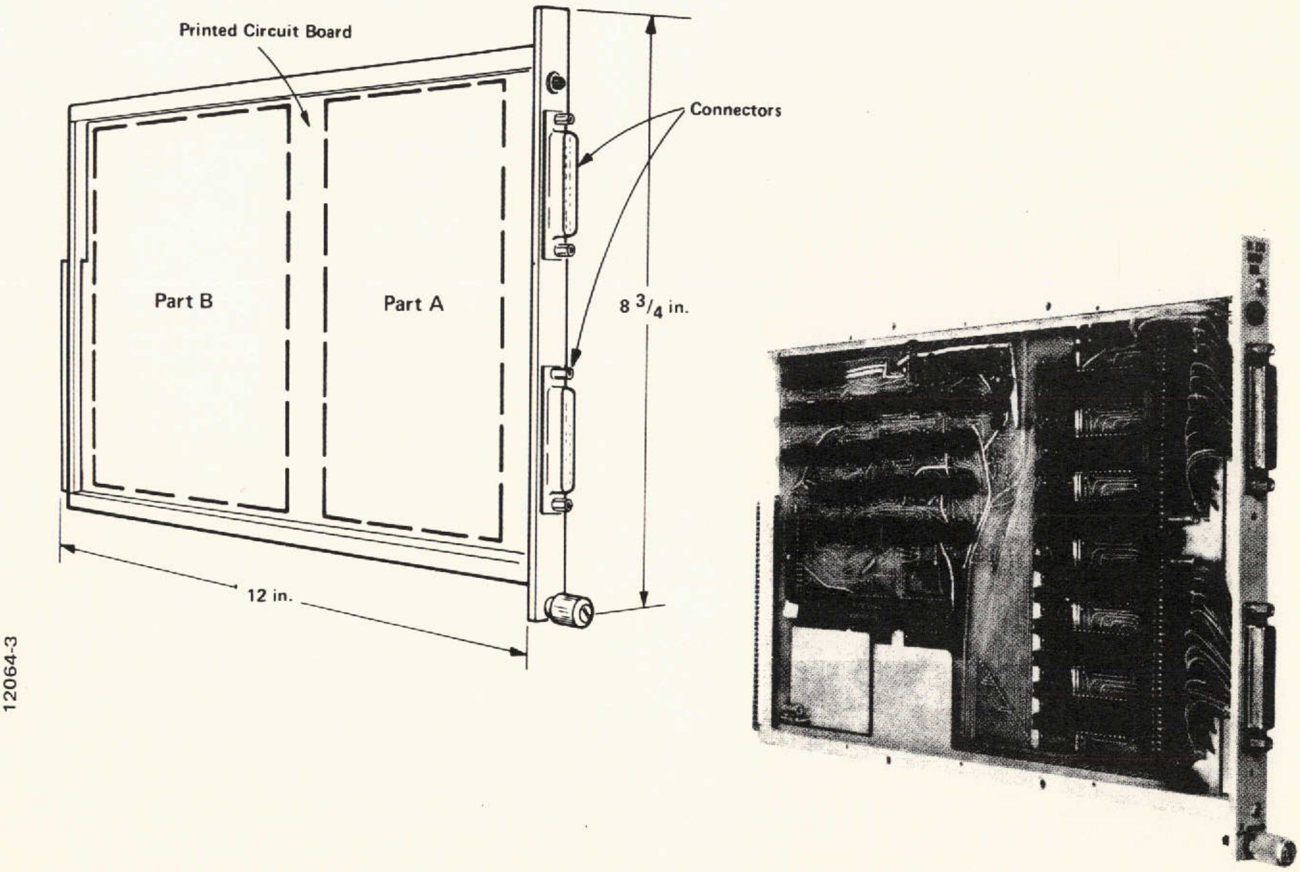


Figure 2-2 CAMAC Module

* This section was excerpted from, "CAMAC, A Modular Communication Bridge," EG and G Ortec, Oak Ridge, Tennessee, 1972.

The module electronics are divided into two sections. Part A of Figure 2-2 contains all the module or function-dependent part; Part B contains all the CAMAC-dependent part, which is the function-code and address-line decoders and other electronics to translate the module functions into CAMAC Dataway language and vice versa.

The module's home is a crate (or bin), shown in Figure 2-3, that secures it mechanically and provides its interface to the power supply and to the Dataway (Figure 2-3b). The usual crate has provision for 25 single-width modules and has 25 card-edge connectors that mate the Dataway to the modules. Twenty-four of these connectors are referred to as "normal stations" and the 25th connector is called the "control station." The size of the crate, including the power supply and ventilation blowers, is 482 mm W x 355 mm H x 525 mm D. The weight is 22.7 kg (50 lb).

The Dataway consists of 48 radially oriented lines and 84 bus lines that go to the connectors on the crate and that are used to transmit signals and power among the crate controller and the modules.

The power buses go to all 25 connectors to distribute the power, which is usually ± 6 V and ± 24 V. Although ± 12V, +200 V, and 117 Vac are available, most systems are based on the 6-V and 24-V lines, because improved compatibility and power supply economy are the dividends for avoiding the use of the other voltages. Total output power per crate is 300 W (450 W input).

The radially oriented lines are between the 24 normal stations and the control station, which is the crossroads of the CAMAC system since all paths intersect at this 25th station. These radial lines are of two types: 24 N, or station, lines, each of which connects to a separate station and must be activated to communicate with the station; and 24 L, or "look-at-me," lines by means of which the individual modules signal the control station that they want attention. The N and L lines are thus private lines, each connecting a specific station to the control station, as distinguished from the party (bus) lines.

The bus lines perform various functions. A number of lines are bused to all 25 stations in true party-line style, but another group of lines are bused to only the 24 normal stations. Of the latter group of lines, 24 are assigned as read lines and 24 as write lines. The read lines transmit up to 24 bits of data from a module, and the write lines transmit up to 24 bits of data to a module. This unidirectional transfer of data reduces the amount of drive capability required of the module.

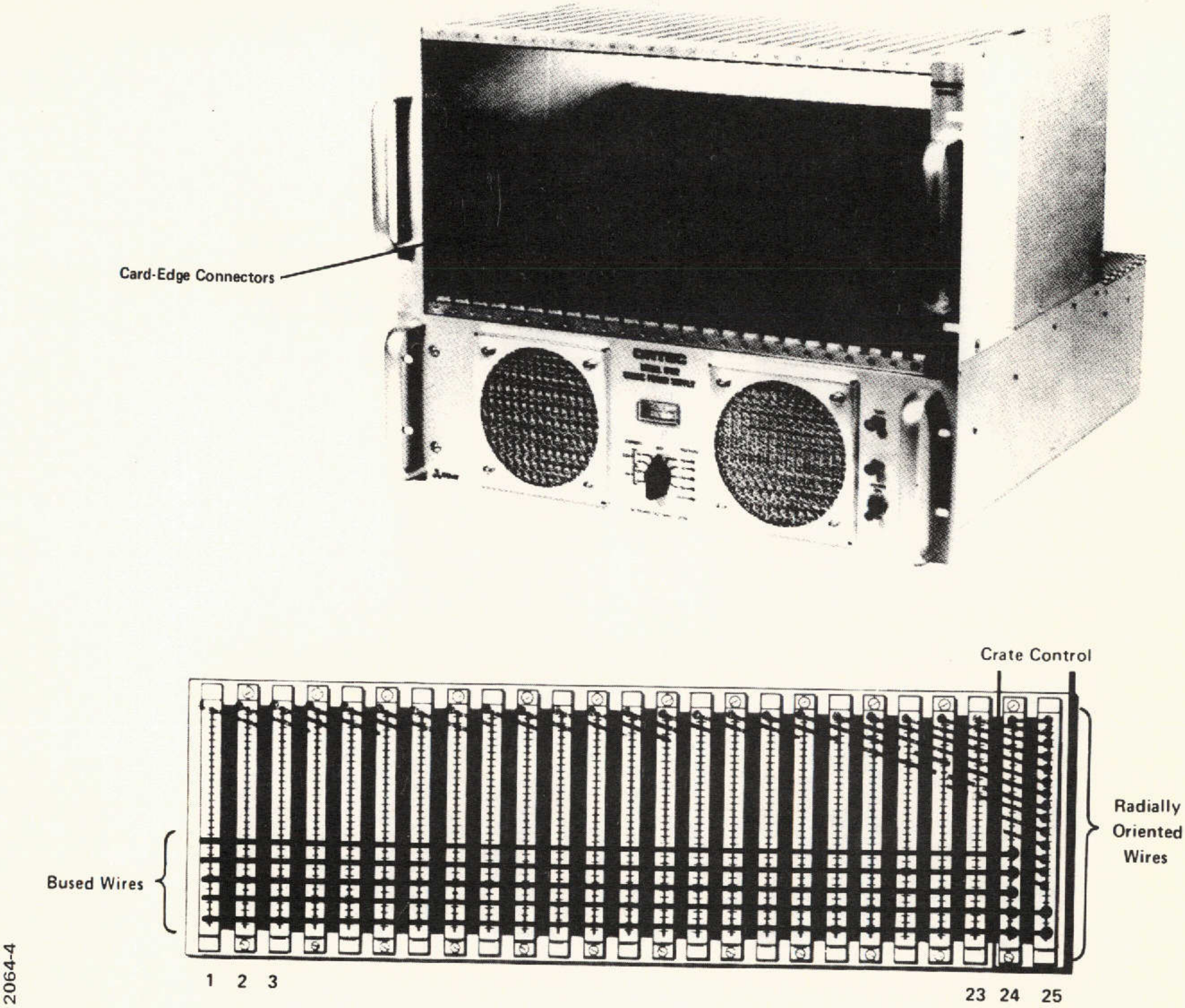


Figure 2-3 CAMAC Crate, Power Supply, and Dataway

Two strobe lines, S1 and S2, are bused to all stations. The strobe signals are generated in time sequence on the two buses and are absolutely necessary for transfer of data or to initiate operations. Other buses include busy (B), response (Q), initialize (Z), inhibit (I), clear (C), and function received (X). These bus line functions are apparent from their names.

The Dataway line groups are summarized in Table 2-2. The patch lines listed are available but are not generally used by manufacturers, which allows the system to be slightly altered to the customer's needs.

Table 2-2

Dataway Bus Line Groups

Name	Function	Number	Name	Function	Number
Read bus; R1 through R24	Carries information from module to crate controller	24	Function code bus	Carries the function code information to the modules	5
Write bus; W1 through W24	Carries information from crate controller to module	24	Subaddress bus	Carries the subaddress information to the modules	4
Power bus: ±6 V, ±24 V, +200 V, ±12 V, returns, 117 V ac, and clean ground	Provides power to modules	14	Control lines	Control various functions, such as initialize, clear, inhibit, command accepted (plus radial lines: interrupt request and station number)	8
Strobe lines	Define the times when the data are stable on the Dataway	2	Spare patch lines	Unused	5

The heart of the CAMAC system is the controller, which occupies the control station and the 24th normal station. The control station issues commands or passes them on (depending on who's in charge) to the various modules. From the control station the controller sends out N signals to the module and waits for L signals from modules that are transmitting "look-at-me" signals. The controller connects to the N and L lines at the control station and to all the buses via the 24th station.

The controller speaks directly to the modules, and the modules speak to the controller but cannot speak to each other or to the outside world without the controller's assistance. Modules are, in general, like simple-minded individuals: they do what they are told to do, except when asking for attention with L signals.

Addressing a module requires transmitting the function code (F), station number (N), and subaddress (A), referred to as FNA, to the crate controller. The crate controller decodes the station number and then activates the N line corresponding to the particular station involved. In addition to activating the appropriate

N lines, the crate controller activates the A and F lines to give a complete command to the module. The A and F lines are fully bused to all stations. Decoding of these lines is done within the modules.

Crate controllers are of three types: stand-alone, dedicated, and branch highway. They are discussed and illustrated in the following sections. The dedicated crate controller is used to connect the computer to the crate for small systems and the branch highway is used for large systems.

Up to now we have implied that a computer is necessary to control the system. This is not always the case. A "smart" controller may be put in a crate to command the modules to do their tasks. The crate may be controlled by a totally manual controller or by a hard-wired controller to do a specific task. A system with such a controller is called a stand-alone or self-contained system. In the example shown in Figure 2-4, the controller is reading the scalers and outputting the information to a printer, cathode ray tube, and magnetic tape. With a modem (MOdulator DEModulator), a stand-alone system can be connected by telephone lines to a remote computer.

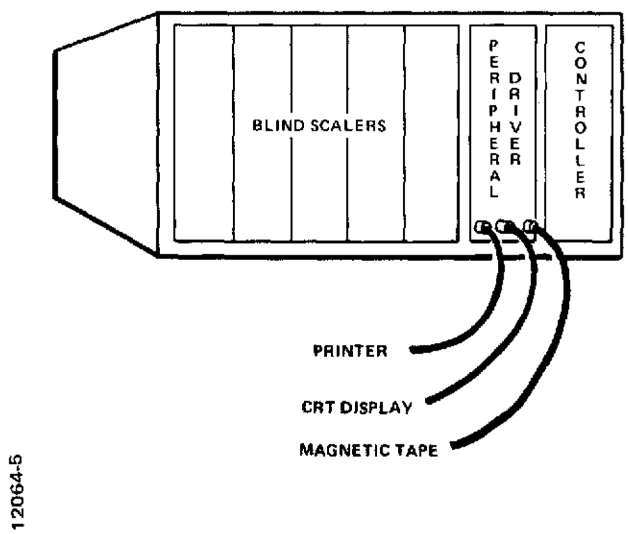


Figure 2-4 Stand-Alone or Self-Contained System

The dedicated crate controller fits into a CAMAC crate and connects directly to the computer I/O (input/output) bus. This means that the controller must speak a language that the computer can understand; thus it functions as an interface to the computer. This type of controller has a CAMAC part and a computer-dependent part, with the computer in control and talking to the modules in a crate through the crate controller. The computer can ask for information and get it from the module, but more important, it can send information out to a CAMAC module.

Control-feedback loops are possible with computer-based systems. For example, the power supply shown in Figure 2-5 is coarsely controlled with a digital input and is fine-controlled with the analog input, and the sense outputs are fed back to the computer via a digital voltmeter to close the feedback loop. The model numbers shown in Figure 2-5 are those of EG&G/Ortec equipment.

In the branch highway system the controller is computer-independent, and the branch driver is computer-dependent. The branch driver, shown in Figure 2-6, can have up to seven crates. Each crate has its own controller, with the branch highway daisy-chained to all the controllers. The branch highway has seven crate address lines to provide a dedicated line for each crate. The address/command of FNA in this case is appended with the crate number to become CFNA.

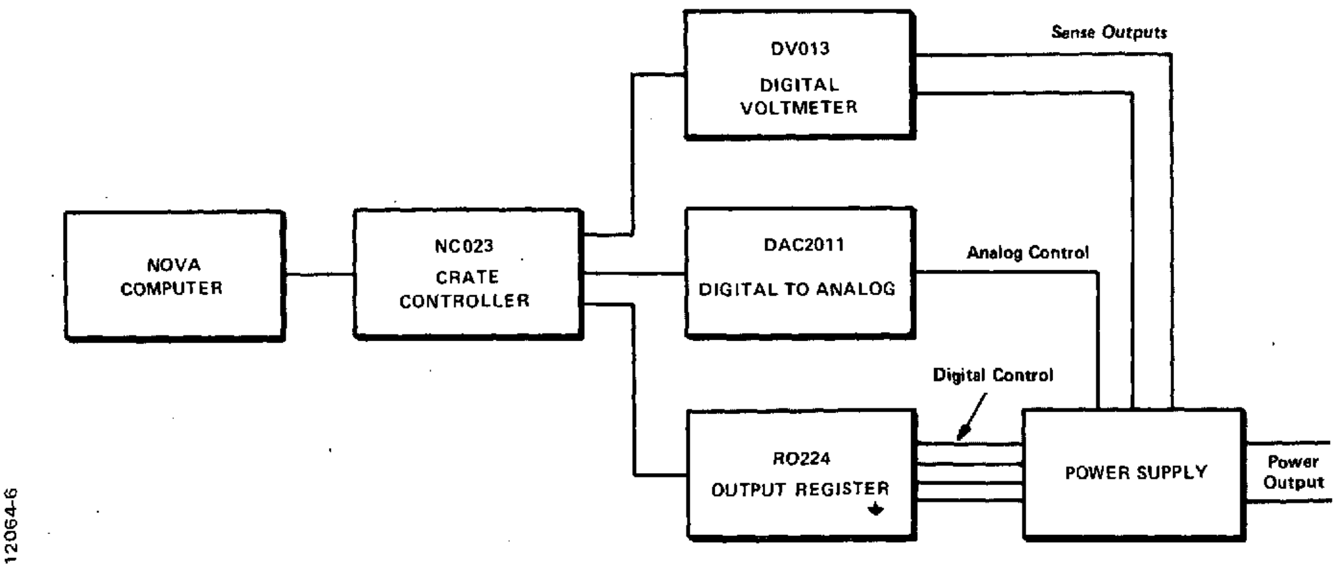


Figure 2-5 Power Supply Control

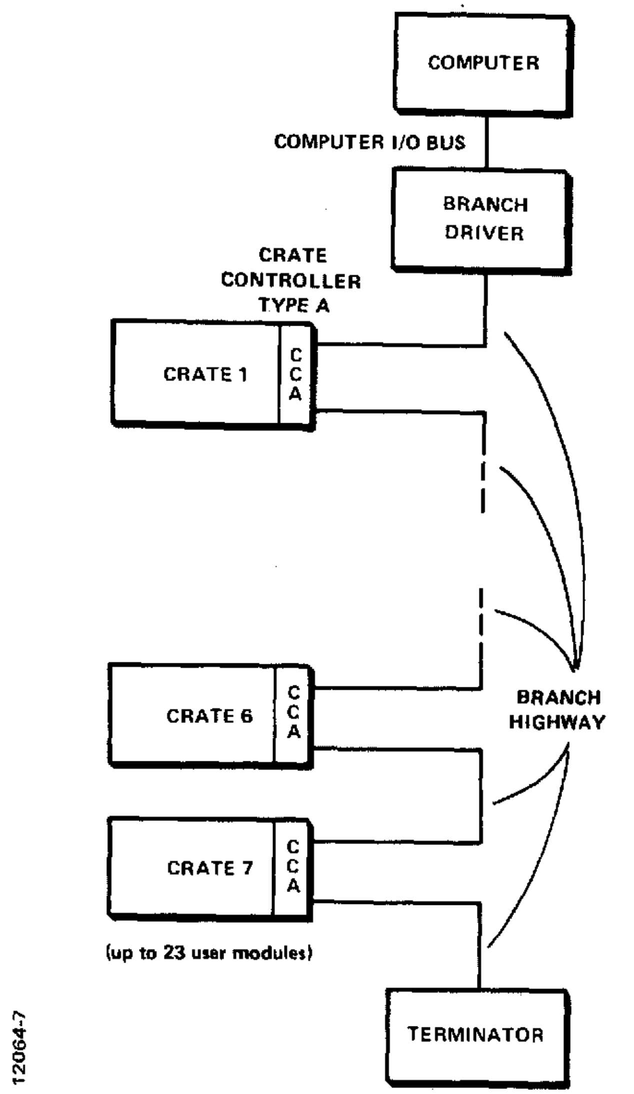


Figure 2-6 Multicrate System

Station number, function, and subaddress lines are contained in the branch highway, but the controller of the addressed crate assumes responsibility for routing these commands within its own crate. The timing signals and timing operations of the branch highway involve the "handshake" type of operations to make the system operation independent of signal transit times in the branch highway. The handshake method involves passing control of the data transfer from the sender to the receiver during each transfer to ensure that no data are lost.

Table 2-3 shows the breakdown of the branch highway into functional groups. The data lines of the branch highway are bidirectional. Since there are seven crate-select lines, any one crate or any combination of crates may be addressed at one time. The lines are grouped in a manner similar to the Dataway grouping. A typical CAMAC system including a branch highway driver is shown in Figure 2-7.

The following steps illustrate the operation involved with a general CAMAC system including a branch driver:

1. The computer loads the branch driver registers; from one to six 16-bit transfers are required to load the branch driver.

2. The branch driver tests the CAMAC code to see whether it is a read, write, or no data transfer. If the operation is a write, the branch driver waits for the computer to load the data register. Otherwise, it begins execution of the CAMAC command by putting the FNA, crate-select, and timing on the branch highway.

3. The selected crate controller decodes the five binary BN lines to the single N line (1 in 32 decoder), passes the F and A lines and the data to the Dataway, and generates the strobe signals.

4. The selected module decodes the F and A lines and takes data from or puts data onto the Dataway. The module also returns the test results and control signals to indicate that it was able to perform the task.

5. The crate controller gates the data and control signals from the crate Dataway onto the branch highway.

6. The branch driver loads the data and control signals from the branch highway into its registers and sets the task-completed bit in its control register.

7. The computer reads the registers for data and error monitoring.

Table 2-3

Branch Highway Line Groups

Name	Function	Number
Read/Write lines; BRW1 through BRW24	Carry data to/from CAMAC Crate from/to Branch Driver	24
Function code lines; BF1 through BF16	Carry function code	5
Station number code lines; BN1 through BN16	Carry station number	5
Subaddress code lines; BA1 through BA8	Carry subaddress	4
Crate select lines; BTA and BCR1 through BCR7	Select crate(s) to be used	8
Crate response lines; BTB1 through BTB7	Carry response of respective on-line crate to BCR and BTA signals	7
Control lines	Carry control and status information	6
Reserved	Unused	7

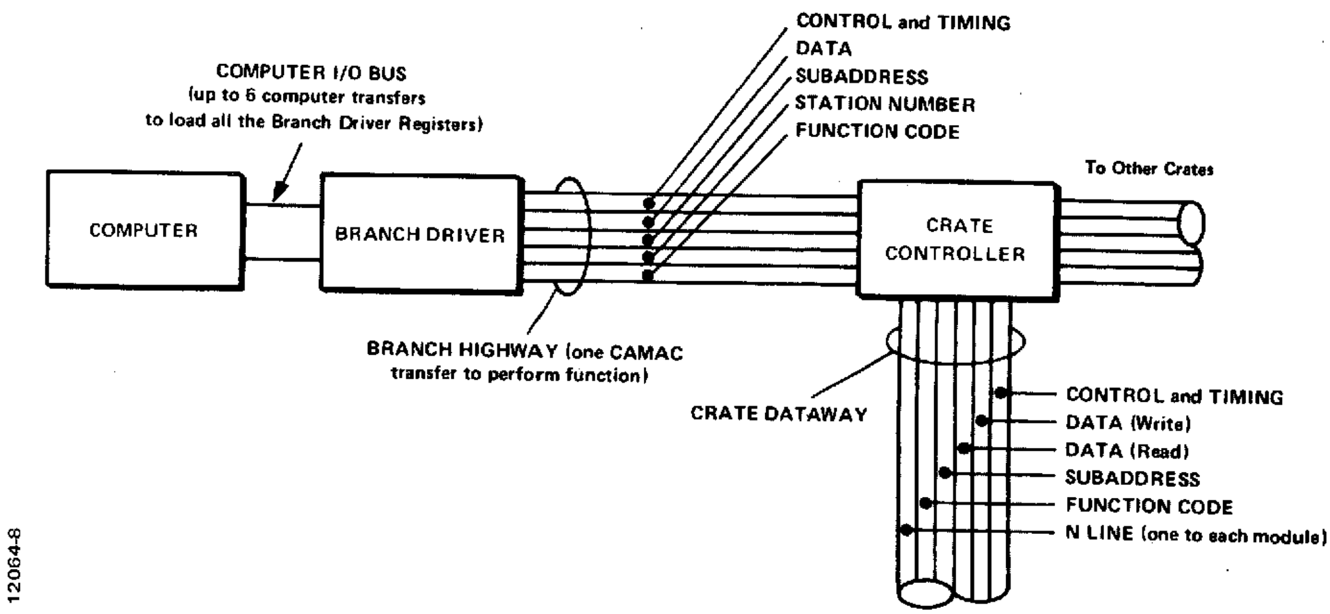


Figure 2-7 Typical CAMAC System with Branch Highway Controller

The amount of time for this sample operation is dependent on computer speed, branch driver speed, and length of the branch highway cable. The crate timing is defined in TID-27875. The crate limits the speed of transfers to 24 bits x 1 MHz.

Although CAMAC was devised by scientific laboratories, it is by no means limited to their applications. A few examples of the varied use of this concept are described below.

One application of CAMAC is the two motor control networks shown in Figures 2-8 and 2-9 for such use as with drilling tables or other automated positioning tables. (Model numbers refer to EG&G/Ortec equipment.) The computer is controlling the motors through the branch driver, crate controller, stepping motor driver, and output register. The motors are driven by their corresponding driver.

The shaft encoder counts the number of revolutions of the shaft to give the position of the table. The limit switches are used to indicate the maximum extent of travel and cause an interrupt in the computer when the table reaches that point.

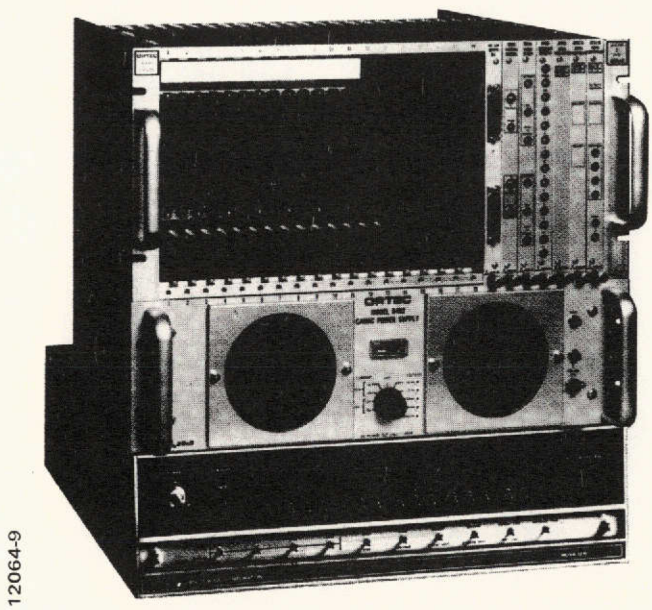


Figure 2-8 EG&G/Ortec Equipment Used in System Diagrammed in Figure 2-9

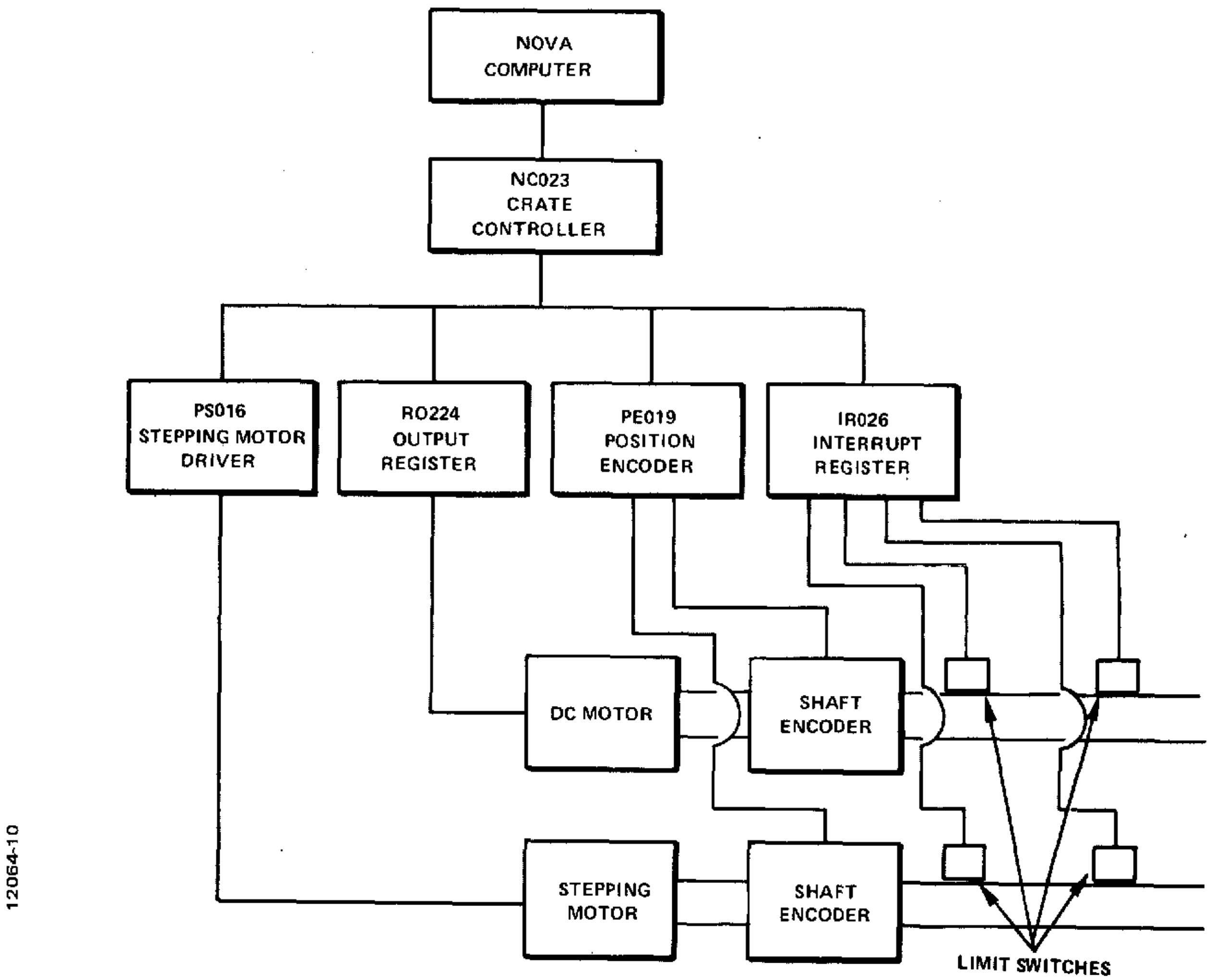


Figure 2-9 Block Diagram of Motor Control System

Another application of CAMAC is the multichannel analyzer built of NIM and CAMAC modules shown in the block diagram of Figure 2-10. The incident radiation is detected in the scintillator/phototube and is integrated in the linear gate. The output of the linear gate is fed into the amplitude encoder. This encoder is an analog-to-digital converter (ADC), but instead of presenting a digital data word, it puts out a serial pulse train that is scaled in an external scaler, which holds the data until they can be read by the computer; the scaler sends a busy flag to the encoder to prevent another signal from being encoded until the scaler has been read. The encoder sends a busy flag to the clocks shown in Figure 2-10 to inhibit them during the digitizing and readout time. One clock contains the live time of the system, and the other one contains the real time (clock time).

When the encoder has finished encoding the pulse, it sends the end-of-conversion signal to the interrupt request register to signal the computer that the data are ready to be used. The data (pulse-height) spectrum can be displayed on the oscilloscope via the three display modules.

A combination system involving motor control systems, radioactivity monitoring, and simple multichannel pulse-height analysis is shown in Figure 2-11. The basic idea in the fuel rod scanning system is the movement of a radioactive rod in front of a detector to measure the radioactivity as a function of length. This system also measures rod diameter, rod length, surface contamination, natural radioactivity in the rod, holes in the rod (missing metal), and fuel enrichment. The data are printed out and records are maintained for each rod. The data also appear on the cathode ray tube terminals so that the operator can tell whether any variables are drifting out of specifications.

Additional description of CAMAC characteristics, applications, hardware, and software is found in the following reference:

IEEE Transactions on Nuclear Science,
April 1973, Volume NS-20, No. 2,
"CAMAC Tutorial Issue."

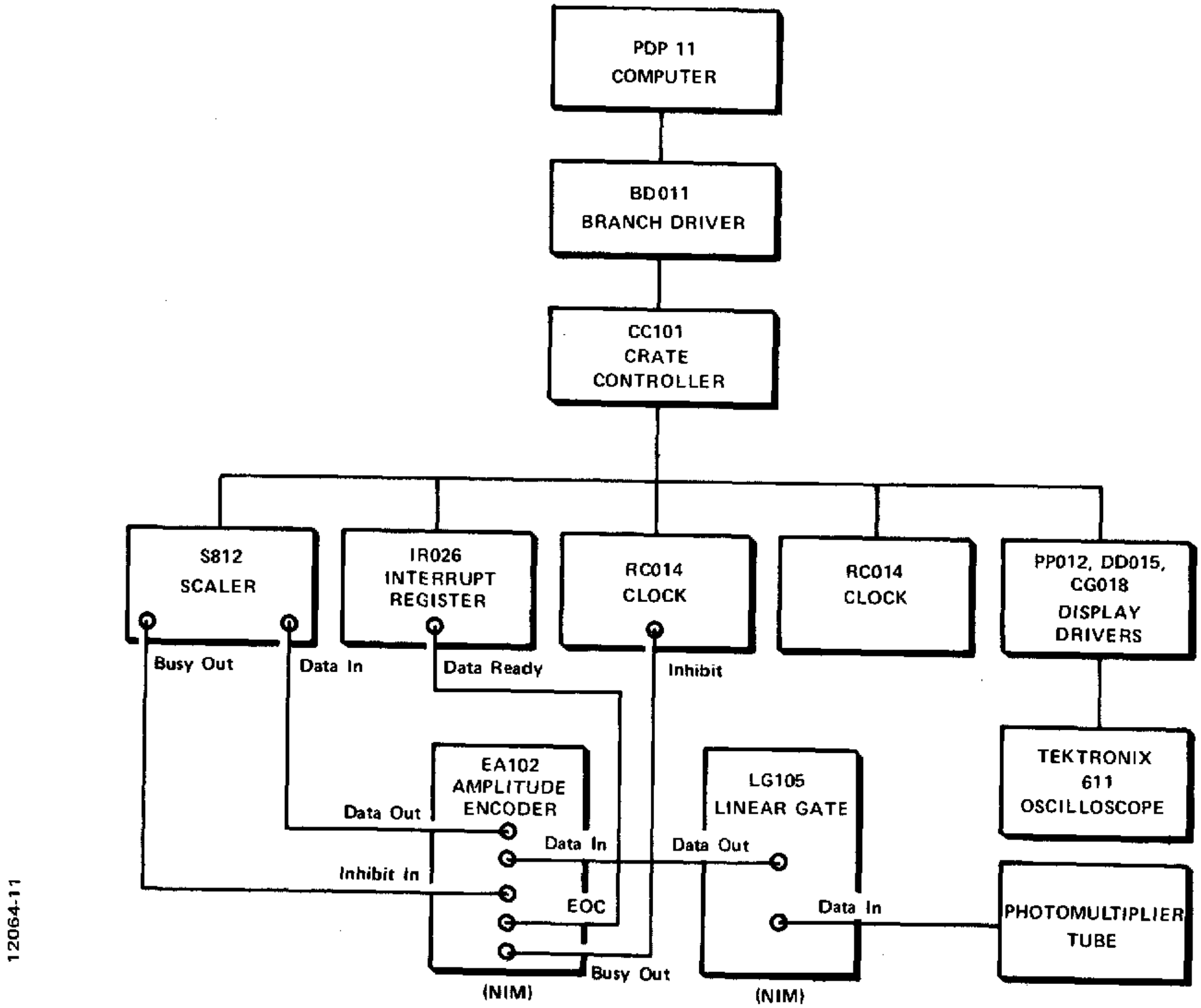


Figure 2-10 Multichannel Pulse-Height Analyzer System

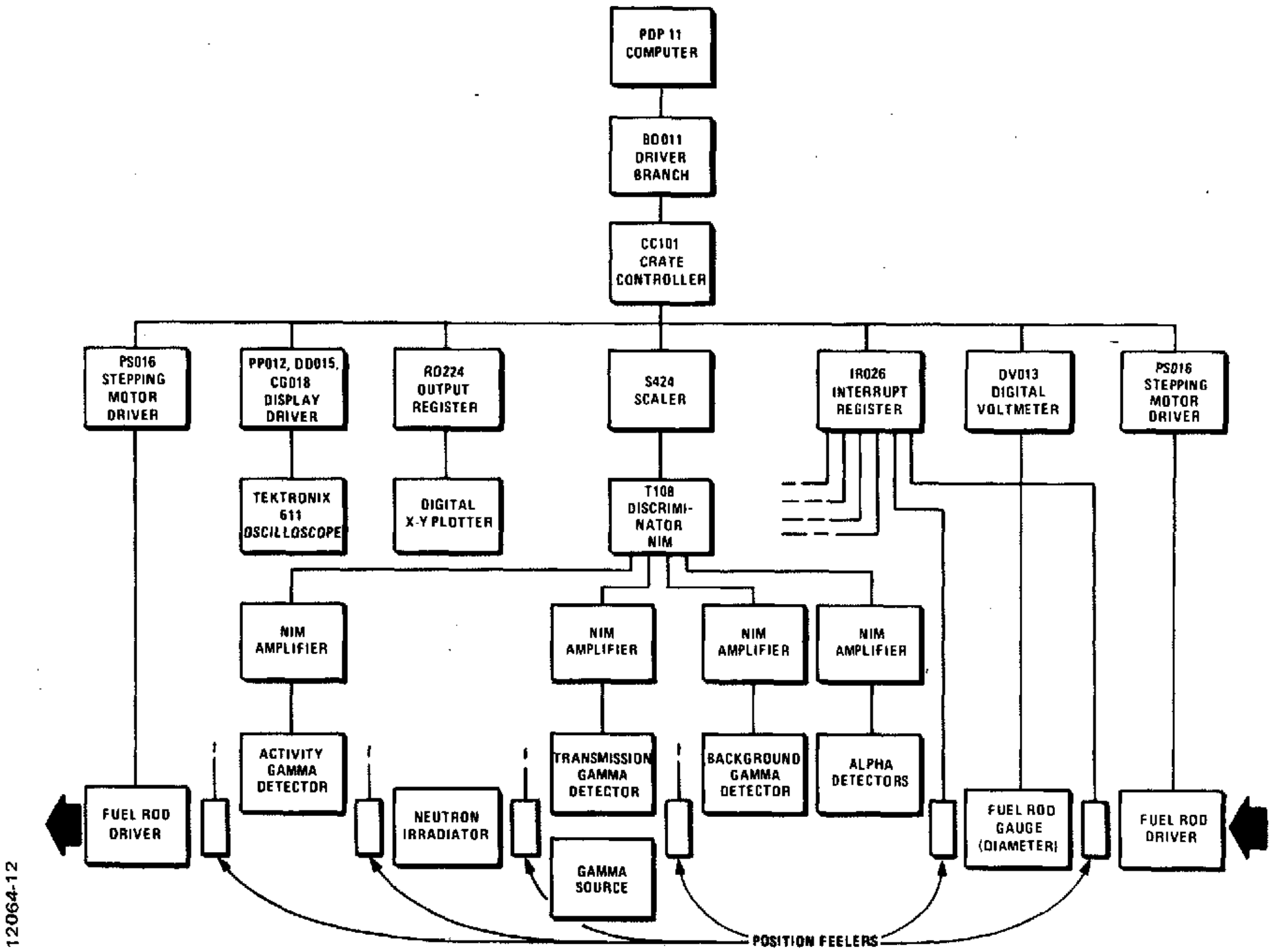


Figure 2-11 Fuel Rod Scanner System

SECTION 3

APPLICATION OF NIM-CAMAC TO SPECIFIC PAYLOADS

Six payloads (Astronomical Observatory for Shuttle, Atmospheric Science Facility, Auroral and Magnetospheric Observatory, Shuttle Sortie Cosmic Ray Laboratory, Orbital 13-Band Multispectral Scanner, and Orbital Microwave Radar System) were selected by NASA for analysis of the feasibility of implementing these payloads with NIM-CAMAC equipment.

The analysis first defined the functional requirements, next identified the NIM-CAMAC standard equipment for each payload, and then tabulated the function, frequency of use, and specification for each NIM-CAMAC equipment. The selection of NIM-CAMAC modules for the functions were from manufacturer's specification sheets. In many cases, a particular module is available from more than one manufacturer. No attempt was made to evaluate which manufacturer was best, and the selections shown should be considered as examples and not a recommendation for the product. Section 4 contains the data sheets for the modules used in the analysis.

CAMAC was found to be of more general use than NIM. NIM modules have been tailored to nuclear instrumentation, and the product line is only slowly expanding to other types of experimentation. In most cases, NIM packaging is an excellent means of packaging and powering the instrument electronics and special NIM modules are shown where it was considered practical.

The general applicability of NIM-CAMAC to the various payloads is shown in Table 3-1 as approximate percentages of the total electronics suitable for NIM-CAMAC implementation. Most experiment digital functions are data processing, sequencing and distributing commands, digitizing analog signals, event counting, and digital control of stepper motors. All of these functions are available with the computer and CAMAC hardware. The other major CAMAC-computer function is experiment control through a keyboard, data display, and data storage. These functions can be performed with either computer peripheral equipment or CAMAC modules. If the data to be entered or displayed require limited computer processing, then the control and display should use CAMAC equipment The advantage of CAMAC control is the use of CAMAC microprocessors for character generators, point plotters, vector generators, CRT or ion discharge display drivers, and keyboard interface functions which allow direct access with the CAMAC modules with only a minimal computer interface. If, on the other hand, the data to be entered or displayed are either to be entered or retrieved from the computer memory, then computer peripheral microprocessors for these functions should be used. Both methods were used in the study and examples of each method are given.

Table 3-1

Approximate Percentage of Payload Electronics Feasible for NIM-CAMAC

Payload	% of Digital in CAMAC	% of Analog in NIM
Astronomical Observatory	80	5
Atmospheric Science Facility	90	0
Auroral and Magnetospheric	90	40
Cosmic Ray Laboratory	100	90
13-Band Multi-spectral Scanner	30	0
Orbital Microwave Radar	95	0

The digital data not suitable for CAMAC are digitized video data. Video data are high rate (≈10 Mbps) and need limited real-time computer processing. Special peripheral equipment was recommended for video data.

The NIM modules meet the requirements for nuclear (including atmospheric particle detector) analog functions. Programmable high voltage power supplies, amplifiers, and discriminators have some use in the other payloads. RF and magnetometer electronics, vidicon electronics, and special preamplifiers and other front end detector electronics are not available in NIM.

Although not discussed in the payload studies, the NIM-CAMAC approach leads to a large amount of cabling between the instrument and the NIM-CAMAC electronics. A need exists for CAMAC modules to provide a serial rather than parallel data interface with the instruments. A serial to parallel shift register in the CAMAC module to interface with remote analog multiplexer A/D converters and input/output registers in the instrument would reduce the cabling between CAMAC and the instruments to a few lines rather than the 16 to 48 lines required with existing modules.

3.1 ASTRONOMICAL OBSERVATORY FOR SHUTTLE

The Astronomical Observatory for Shuttle (AOS)* is conceived as a 1-meter aperture, near-diffraction limited telescope which delivers its focal surface to a shirtsleeve environment inside a Sortie Laboratory, for operation with a variety of general-purpose instruments and detectors during Shuttle Sortie missions. Astronomers will be invited to perform their own observations in situ with the instrumentation. The objective is to provide a national space observatory which is available to the astronomical community for conducting a wide range of observing programs in the ultraviolet (UV) and visible portions (900 to 7,000 Å) of the spectrum.

3.1.1 Observatory Description

The major components for the AOS consist of telescope, echelle spectrograph, imaging spectrograph, SEC vidicon and electronographic detector systems, offset guidance system, and an optical bench. The performance of the AOS instrumentation is summarized in Table 3.1-1. The AOS configuration is shown in Figure 3.1-1. The telescope is mounted outside the Sortie Lab, whereas the focal plane and instrumentation are accessible to the observer inside the Sortie Lab.

The telescope, which is supplied with two secondary mirrors for either f/10 or f/25 operation, is bearing-mounted to the aft bulkhead of the Sortie Lab. The mount permits telescope motion within a 90° arc about the "azimuth" axis and a 30° arc about the "elevation" axis (see Figure 3.1-1).

Internal to the telescope, between the primary and secondary mirrors, is a tertiary mirror. A bearing-driven intermediate servo coarsely positions the tertiary mirror cell to reflect the beam into the airlock. Within the cell is the fine position servo for the tertiary mirror. This is a two-axis servo, which performs the final positioning of the image at the telescope focal plane.

Internal to the Sortie Lab and aligned to the azimuth axis of the telescope is an optical bench on which the various instrumentation packages and the fine guidance error sensor are mounted. The optical bench is bearing-mounted and provides image roll position control as well as telescope focus adjustment. Roll position error information is derived from a sensor which is mounted orthogonally to the telescope optical axis.

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*Astronomical Observatory for Shuttle, Study Summary and Final Report, BBRC F72-09, Ball Brothers Research Center, Boulder, Colo., Jan 1973. The Observatory Description is excerpted from the report.

Table 3.1-1

AOS Telescope and Spectrograph Performance

Telescope

Type - Ritchey Chrétien at f/25/Modified Coudé
Aperture - 1 meter
f/Ratios - f/25 or f/10
Useful Field Diameter -- 30 min at f/25
-- 34 min at f/10
Image Quality - 0.4 sec at -- 11.0 min at f/25 (80 mm dia)
- 0.3 at -- 13.75 min at f/10 (40 mm dia)
Pointing Accuracy - 0.028 sec rms, f/25
- 0.077 sec rms, f/10

Echelle Spectrograph

Spectral Range - 1,150-7,000 Å (three ranges)
Resolving Power - 1.2×10^5

Imaging Spectrograph

Spectral Range - 1,150 - 7,000 Å (multiple ranging)
Resolving Power - 10^4

Lyman Spectrometer

Spectral Range - 900 - 1,200 Å
Resolving Power - 10^4

Telescope Assembly - The telescope assembly chosen for the AOS is designed to form $\approx$0.2 arc second images over a 14-arc minute field. A 1-meter primary is used in conjunction with one of two selectable secondary mirrors to give the assembly an effective focal length of either 10 or 25 meters. The figure of the mirrors is chosen so that the Ritchey-Chrétien criteria are satisfied at f/25 and spherical aberration is corrected at f/10. A plane, tertiary mirror redirects the beam from the telescope axis to the focal plane within the Sortie Lab. The telescope is thus a Coudé in effect, but the two rigidly mounted mirrors of the Coudé are replaced in the AOS by a single mirror that must be accurately and actively aligned in two axes, thus compensating for both azimuth and elevation errors in the telescope axis which result from vehicle motion.

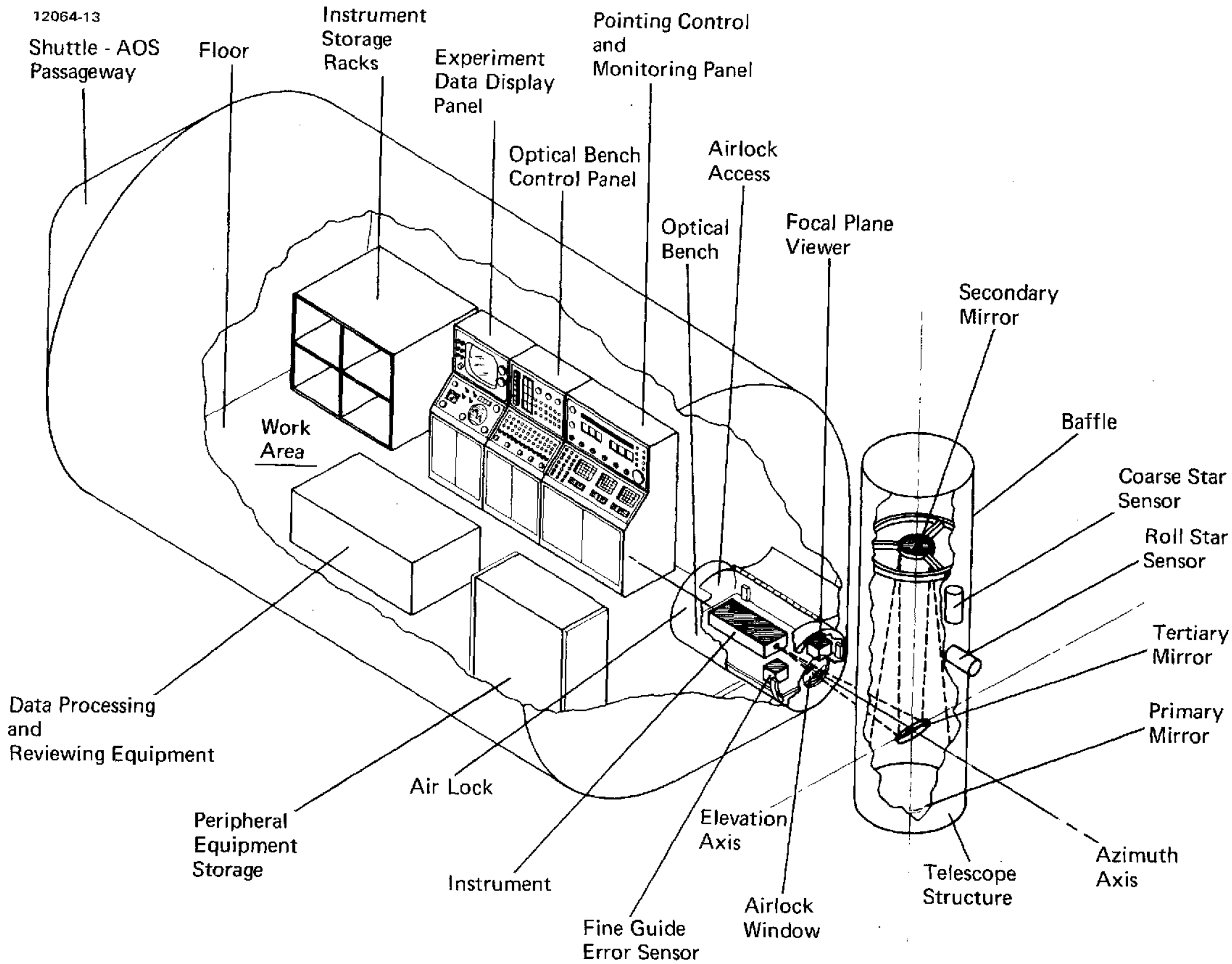

Figure 3.1-1 AOS Configuration

Echelle Spectrograph - The design for an echelle spectrograph provides a resolving power of $\approx 10^5$ over the 1,150 - 7,000 Å range in approximately one-octave segments. The design is similar to the one proposed for LST, but it has no aspherical elements. An approximately 1-meter focal length is used.

When configured for high resolution, an f/10 camera is used, and the spectrum is recorded with an SEC vidicon. A second configuration is available using a fast electronographic camera. The cameras can be interchanged during flight.

Imaging Spectrograph - An imaging spectrograph has been designed to provide a spectral resolving power of $\approx 10^4$ over the full field in the dispersion direction, and 0.35 arc second spatial resolution along the slit. An f/10 camera is provided for operation with an SEC vidicon. A fast electronographic camera can be used at f/1. The cameras and spectral segments are interchangeable in flight.

3.1.2 Electronics

There are five main functional blocks for the electronics: (1) telescope and optical/bench control, (2) pointer control and monitoring panel, (3) optical bench control panel, (4) instrument electronics, and (5) experiment data display. These blocks are shown in Figure 3.1-2.

Telescope and Optical Bench Control - The telescope structure is gimbaled in azimuth and elevation for coarse pointing. Fine guidance pointing is accomplished by controlling the two-axis gimbaled tertiary mirror. In addition, the optical bench inside the airlock is gimbaled in the roll axis to control the slit aperture orientation and correct for image smearing due to shuttle vehicle motion. Direction error sensing for the various tracking loops is provided by star sensors. A two-axis wide field of view star sensor mounted on the telescope assembly is used in controlling the coarse guidance telescope acquisition and tracking. The fine guidance error sensor is mounted on the roll-stabilized optical bench, and the roll star sensor is on the telescope assembly, mounted orthogonal to the coarse guidance sensor. The star trackers send the error signals in digital words to a central processor, which in turn generates the proper commands to the stepper motors.

Pointer Control and Monitoring - Operation of the three servo control mechanisms (coarse and fine pointing, and optical bench) will be done from a pointer control and monitoring panel. The panel has keyboard and tape computer access capability for programming target coordinate information into the computer. The panel has digital displays of the error signal from each axis as well as a display to which the individual housekeeping (labeled HSK in Figure 3.1-2) functions can be individually switched and monitored.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

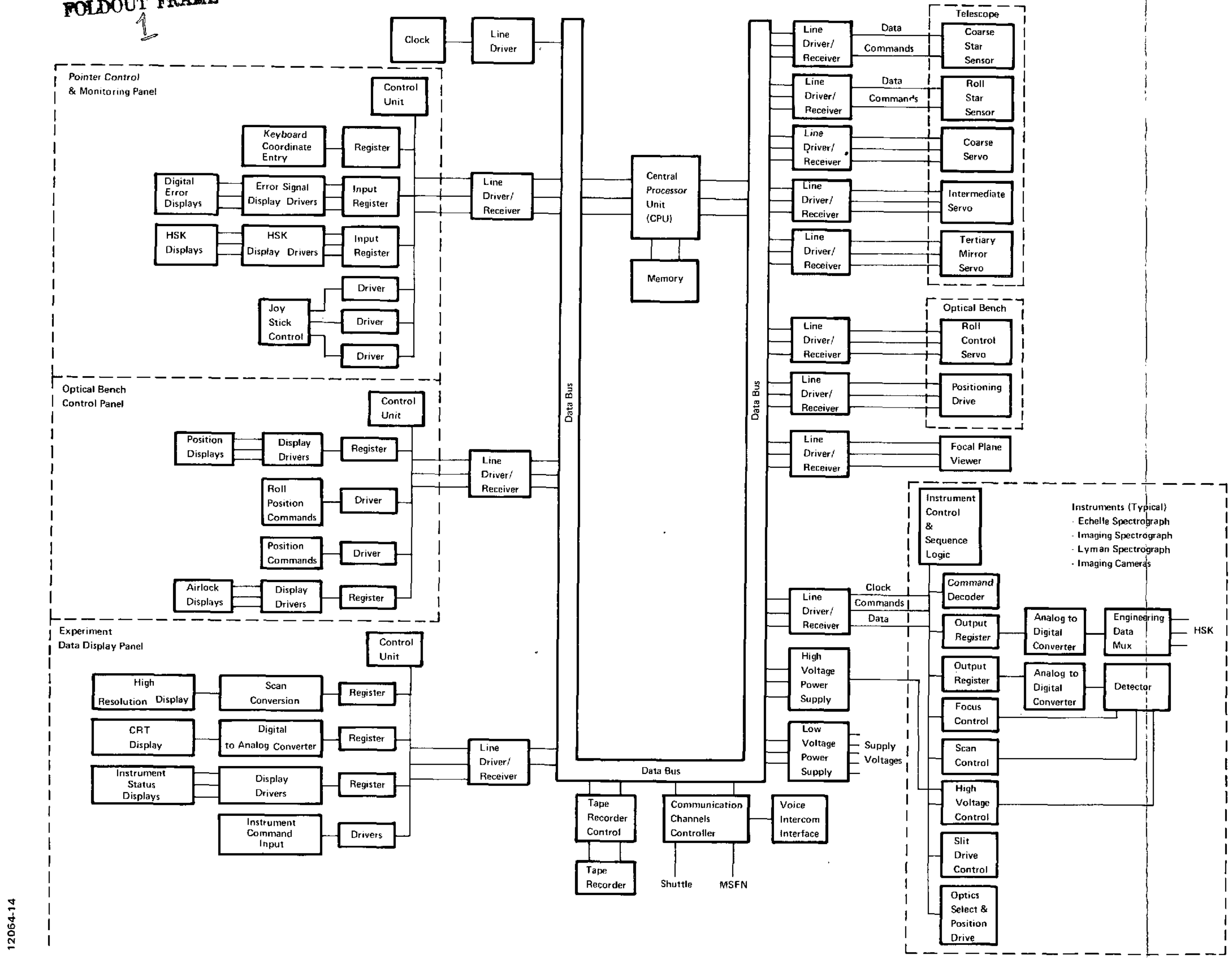

Figure 3.1-2 Astronomical Observatory for Shuttle — Functional Block Diagram

The panel has a "joystick" that can be used as a high-resolution control to permit the payload specialist to precisely position the telescope optical axis. This will be done while viewing the output of the focal plane viewer (SEC Vidicon System) located on the experiment data display panel.

Optical Bench Control Panel - The optical bench has the capability of being remotely positioned to align the entrance aperture and also to position the aperture precisely at the telescope focal plane. Mechanical registration surfaces are provided for mechanical positioning of the experiment packages, and final positioning will be made by moving the bench with its various drives and monitoring the data display panel. Translational motion, horizontal and vertical, and rotational motion are provided. Translational motion is used to position the entrance aperture on the focal point of the target of interest, and rotational motion is used to align the experiment optical axis to the telescope optical axis.

The optical bench is mounted inside a limited set of roll bearings. The roll motion is servo controlled (see Telescope and Optical Bench Control), and the optical bench control panel allows the payload specialist to set in the desired roll position and that position will be automatically maintained.

The entire optical bench assembly will be contained within an airlock. Optical access to the airlock is through a quartz window. A growth concept is to allow the window to be opened remotely from the optical bench control panel.

Instrument Electronics - The AOS is designed for use with general- and special-purpose instruments. The general-purpose instruments are the echelle spectrograph, imaging spectrographs, Lyman spectrograph, and the imaging cameras. These instruments use either an SEC vidicon or an electronographic camera.

The instrument functions that interface with the central data processor are the optics selection and position drives and the slit drive mechanisms. The detector functions are the focus control, scan control, high voltage control, high frequency clock (10 MHz), and data output. These functions are similar for all of the instruments and a single electronic support module can be used. Special electronics that do not interface with the central data processor are required for the vidicon and power supplies.

The electronographic camera uses electron-sensitive film for integrating and storing the image. No data electronics are required for this detector. The SEC vidicon, on the other hand, gives electronic data which can be computer processed and displayed in real time for quick look analysis. The vidicon output is digitized and then sent to the central processor unit.

New investigations in astronomy use single photon counting and multiscalers to integrate the photon counts in each resolution element (pixel). A recent detector developed by Boksenberg* uses a plumbicon and a logic circuit to determine the most likely position on the photocathode where the photoelectron conversion took place. Other detectors which show more promise use a photocathode, intensifier, and a charge coupled device (CCD) for readout. The output of this device is read out at clock frequencies from 100 kHz to 10 MHz. The output is discriminated at about 3σ above noise to determine whether a photon was registered in a pixel, and a photon "tag", which identifies the pixel, is sent to the multiscaler.

The multiscaling function is similar to that used in nuclear experiments, and CAMAC/computer hardware has been developed for this function (see Section 2).

Experiment Data Display Panel - This panel provides the payload specialist with monitors for the data output and a monitor to view the field at the telescope focal plane. The panel primary components are a scan conversion system, a high resolution display, and a storage tube display.

The scan conversion system takes the output from either the SEC vidicon used to view the telescope focal plane or the SEC vidicon used to collect data. Scan conversion is required because the SEC scan rate is expected to be much slower than the rate required for visual viewing on the display.

The storage tube display is used to display data, in pulse height form, of the line spectra at the exit of the imaging spectrograph mounted on the optical bench.

3.1.3 NIM-CAMAC Implementation

Most of the electronic functions are associated with the telescope and optical bench, pointing, and monitoring displays. Except for the TV display, these are all available in standard CAMAC and minicomputer commercial hardware. The instrument computer interface electronics for the instruments are CAMAC-compatible and some of the instrument analog electronics are available in NIM. Figure 3.1-3 shows the NIM-CAMAC modules.

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*A. Boksenberg and D.E. Burgess, "The University College London Image Photon Counting System: Performance and Observing Configuration," Dept. of Physics and Astronomy, University College London.

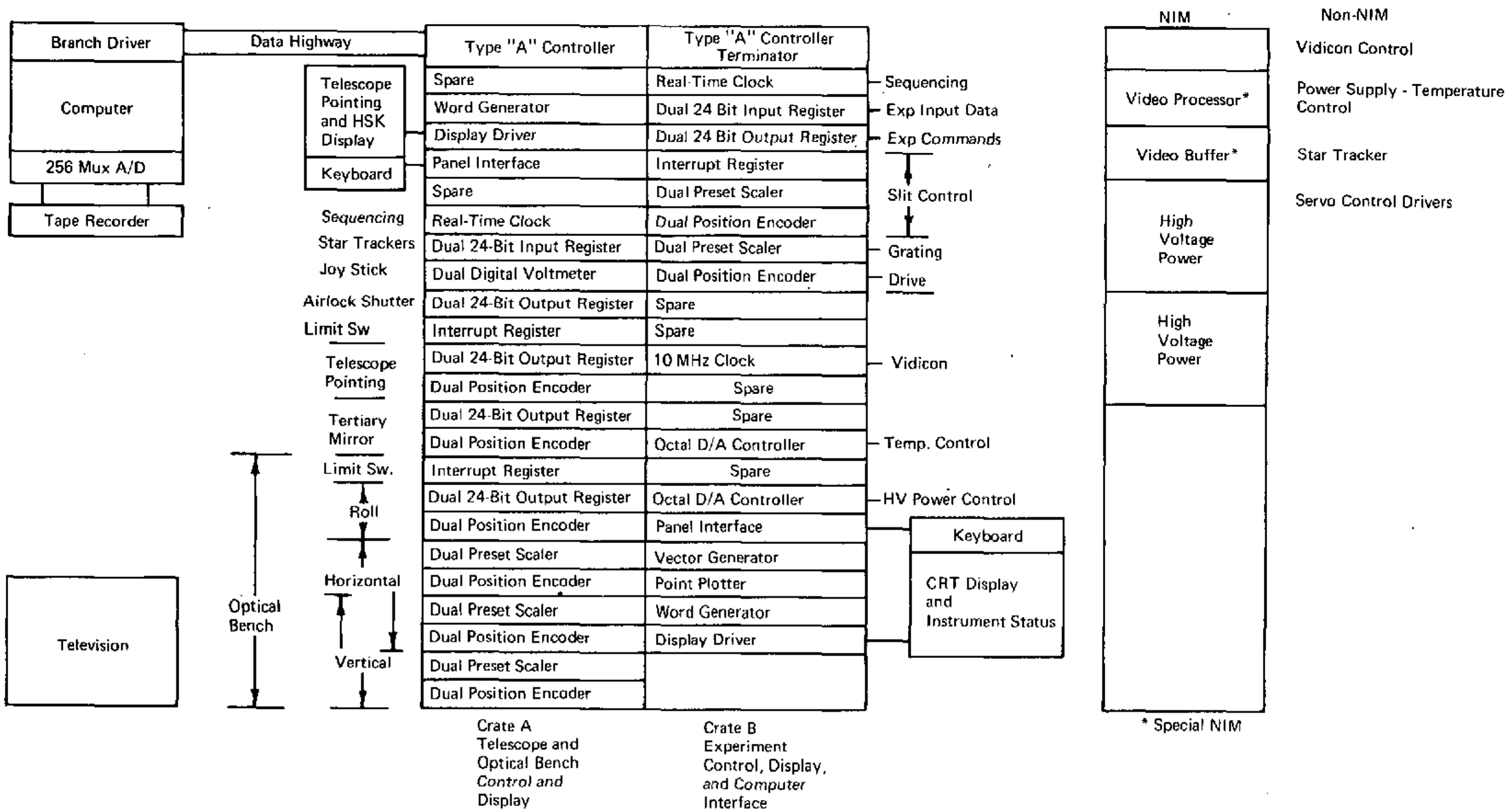

Figure 3.1-3 Shuttle Astronomical Observatory

Two means of using CAMAC for motor control were described in Section 2. One is to send a word from a 24-bit output register to a dc servo control torque motor; the second is to send a pulse train to a stepper motor. Both methods use position encoders for feedback to the computer to assure that the position was reached. The brushless dc torque motor provides high torque and is used on the telescope, tertiary mirror, and optical bench roll axis. A separate servo control analog subsystem drives the motors to the prescribed angle. Stepper motors are used for the lead screw positioning of the optical bench, and for filter wheels, slit adjustments, etc., in the instrument. Two types of CAMAC stepper motor drives are available. One, manufactured by EG&G/Ortec, sends a pulse train at a constant frequency; the other CAMAC stepper motor drive, manufactured by Kinetic Systems, sends out a variable frequency that starts at zero, accelerates to a preset value, then decelerates to zero frequency at the final pulse. Data sheets on these two modules are included in Section 4. The constant frequency stepper is adequate for light duty requirements, and the variable frequency stepper is adequate for heavier duty.

The telescope and optical bench drives and display require a CAMAC crate. Each drive motor requires a position encoder and a 16-bit motor controller command. The telescope pointing motor controller command comes from either the star tracker, a keyboard or tape stored commands, or the joystick. The error signal from the star tracker is sent in digital form to an input register. The command to direct the telescope to a new stellar object is first entered from the keyboard, and a stored subroutine computes the necessary motor controller steps to acquire the object. The joystick generates an analog signal which is fed into the two channels of the CAMAC digital voltmeter. Once the motor controller steps are determined by the computer, the computer addresses the telescope pointing output register which then advances the dc motor in the telescope. The position encoder measures whether the proper number of position steps have taken place; if they have not, the computer directs the motor controller to the correct number of steps. This process is repeated each time a new pointing command from any of the three inputs (star tracker, joystick, or keyboard) is generated.

Limit switches are placed at ends of travel of each motor. This allows an override of any computer commands that accidently exceed the limits of travel. The limit switches feed an interrupt register, which interrupts the motor so as to prevent further travel until new commands are sent to the stepper motor. Commercial interrupt registers with 12 inputs are available. One CAMAC module is used with six pairs of dual preset scalers and dual-position encoders.

The remaining position controllers for the tertiary mirror and optical bench use the same type of CAMAC control as the telescope pointing. The optical bench translational motion requires two stepper motors at each of the three mounting points. The vertical control shares one-half of the dual preset scaler and dual-position encoder with the horizontal control.

A dual 24-bit output register is used for actuating shutters and the airlock and uncaging the telescope and optical bench. The digital error display, housekeeping display, optical bench position display, and airlock display use a keyboard and display driven by CAMAC modules. Microprocessor modules for character generators, panel drivers, and panel interface relieves the computer for these functions. This allows the computer to be dedicated to sequencing, tracking computations, and data processing. The character generator can display 64 lines of characters (1, 024 raster lines) with 64 characters (1, 024 dots) per line.

The housekeeping analog lines are fed into a 256-channel multiplexer that is a peripheral piece of computer equipment. Analog multiplexers are available in CAMAC in 12 to 16 inputs per module, but the large amount of housekeeping data associated with the observatory makes the use of peripheral computer equipment a lower cost approach.

The experiment control display and computer interface require a second crate. The crate contains a real-time clock for sequencing, a dual 24-bit input register for receipt of digital data from the vidicon, and a dual 24-bit output register to command the instrument functions. The modules required for stepper motor drive are provided for spectrometer entrance slit adjustments and for changing the angle of the grating mounts. A 10-MHz clock provides the scan drive for the vidicon. The output frequency of the clock can be changed by computer/CAMAC instruction to give lower frequencies for slower vidicon scan rates.

Dual digital-to-analog (D/A) controllers provide analog CAMAC-controlled analog voltages for temperature and high voltage control. The housekeeping temperature sensors provide data words to the computer, which compares the temperature with stored values and then directs the D/A converter to apply a proportional heater control. On/off temperature control uses commands through the experiment CAMAC output register. Similarly, the high voltage power supplies for the electronographic camera image intensifiers, the photometer photomultiplier, and the intensified CCDs are D/A converter controlled from either housekeeping data or by the payload specialist entering high voltage values through the keyboard.

The experiment data display panel is similar to the telescope panel except that a CAMAC point plotter and vector generator are added. These modules allow spectra to be integrated and displayed on the storage CRT. The vector generator allows the spectra "dots" to be joined with a line plot of the data. The payload specialist can enter, through the keyboard, commands to display the spectra over the entire bandwidth of the spectrometer or to select a narrow band and expand the narrow band over the total width of the CRT display. Standard NIM modules are available for the high voltage power supplies for the electronographic cameras. Video processor and video buffer amplifiers could be packaged in single-width NIM modules. The vidicon controls, power supplies for temperature control, and star tracker electronics are the major nonstandard electronics. The weight, power, and cost summary for the NIM and CAMAC modules is shown in Table 3.1-2.

Table 3.1-2

NIM-CAMAC Weight, Power, and Cost Summary

CAMAC Modules	Weight (kg)	Power (W)	Cost ($)
Branch Driver BD-011[a]	11.4	60	4,800
Crate-Power Supply (2) MC100[a]	45.4	260	3,090
Type "A" Controller (2) CC101[a]	2.8	24	2,700
Word Generator (2) CG018[a]	17.4	17.4	1,970
Display Driver (2) DD015[a]	4.4	4.44	1,020
Panel Interface (2) (Estimated)[a]	2.8	16	3,000
Real-Time Clock (2) RC014[a]	1.6	8.64	1,190
Dual 24-Bit Input Register (2) RI224[a]	1.8	12.0	1,050
Dual Digital Voltmeter DV013[a]	0.9	6.35	705
Interrupt Register (3) IR026[a]	2.4	8.64	1,185
Dual 24-Bit Output Register (5) RO224[a]	4.5	30.0	2,875
Dual Preset Scaler (5) PS016[a]	4.5	20.7	3,800
Dual Position Encoder (8) PE019[a]	4.8	53.04	6,320
10-MHz Clock CG[b]	0.68	8	395
Octal D/A Controller (2) 3110[c]	1.0	14	1,290
Vector Generator VG028[a]	0.9	6.76	850
Point Plotter PP012[a]	0.9	6.78	985
Terminator BD-01[c]	0.1	1.8	295
NIM Modules			
High Voltage Power (2) 456[a]	7.0	100	1,020

( ) Numbers in parentheses are the number of required modules.
(a) Manufactured by EG&G/Ortec.
(b) Manufactured by Joerger Enterprises.
(c) Manufactured by Kinetic Systems.

3.2 NIM-CAMAC ATMOSPHERIC SCIENCE FACILITY

The Atmospheric Science Facility (ASF) described in this section is based on the previous ASF studies referenced in Section 3.2.6.

3.2.1 ASF Configuration

The Sortie Lab ASF configuration is shown in Figure 3.2-1. The ASF instruments are grouped into three clusters: main instrument cluster, solar monitor, and previewer. Each cluster is mounted in a three-axis gimbal mount under control of the ASF operator and/or pointing computer. All instruments in each cluster are boresighted to a common line of sight. All experiment operations, controls, data displays, processing, and recording are internal to the pressurized Sortie Lab module. The Sortie Lab ASF is largely independent of the Shuttle except for basic altitude and attitude control, ground communication, and data on Shuttle attitude, position, and time. Figure 3.2-2 shows the location of key ASF components.

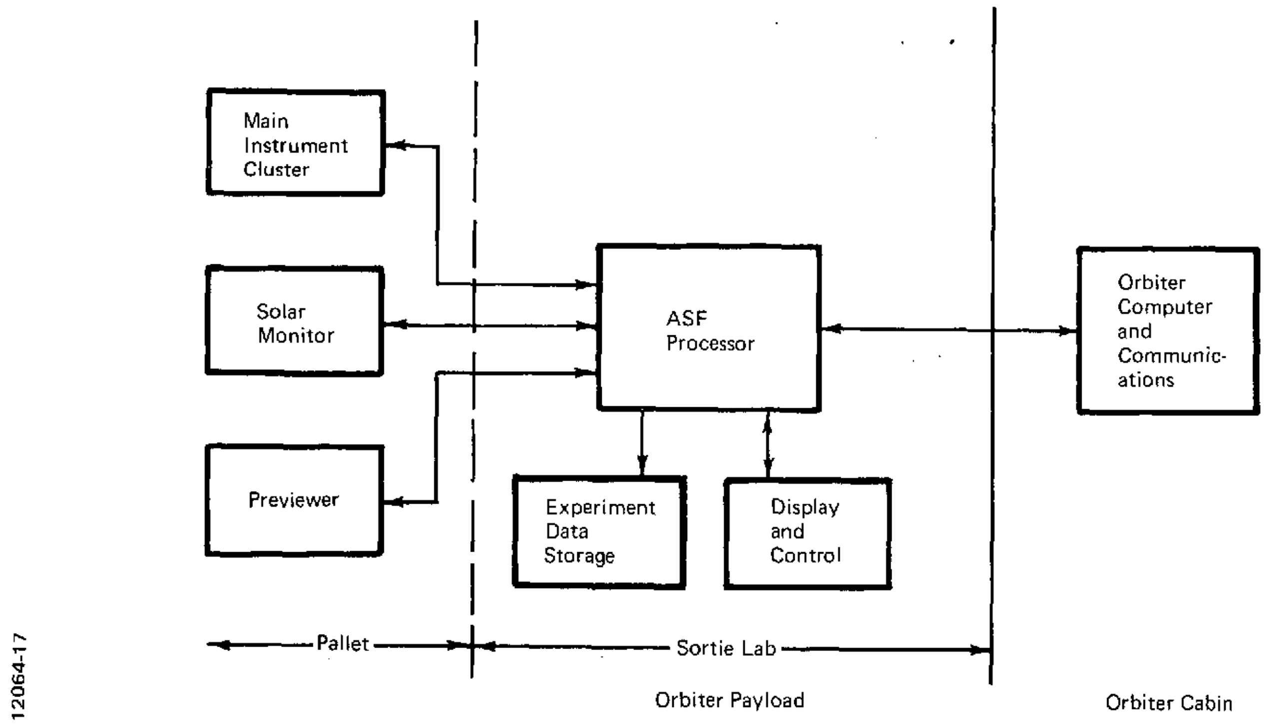

Figure 3.2-2 Location of Key ASF Components

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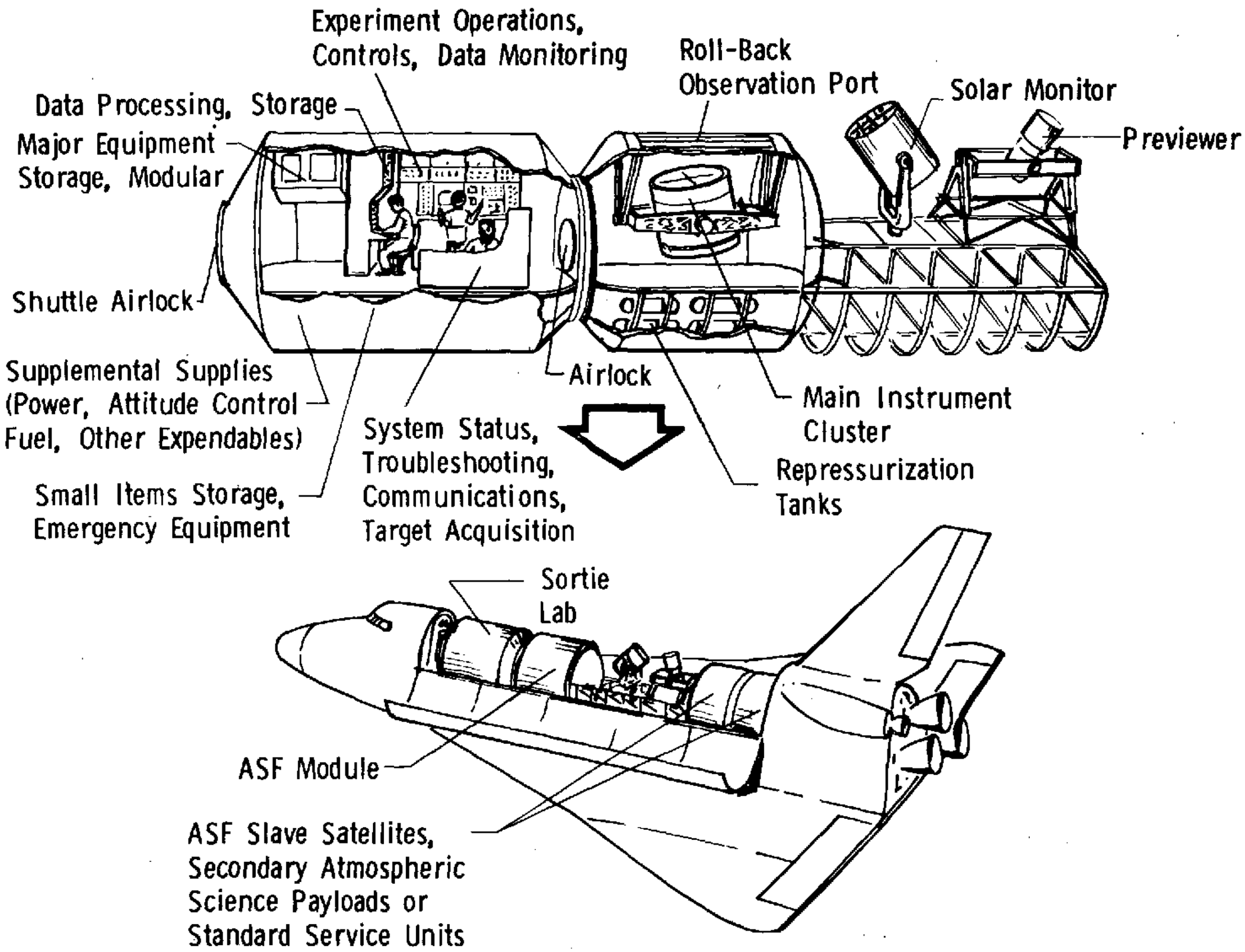


Figure 3.2-1 Sortie Lab ASF Configuration

Instruments of the Main Instrument Cluster (MIC) are shown in Figure 3.2-3a, and the gimbal system is depicted in Figure 3.2-3b. Torque motors drive the gimbals under control of a special ASF guidance computer. Guidance references are a rate-stabilized gyro inertial reference, which is updated periodically by star tracker sightings. The MIC guidance and control system provides cluster pointing and stability, generates scan patterns, and provides pointing data. Performance requirements for the MIC pointing and control system are given in Table 3.2-1. In operation, the MIC scans a programmed path, is slaved to the previewer, or is pointed under direction of joystick operator control.

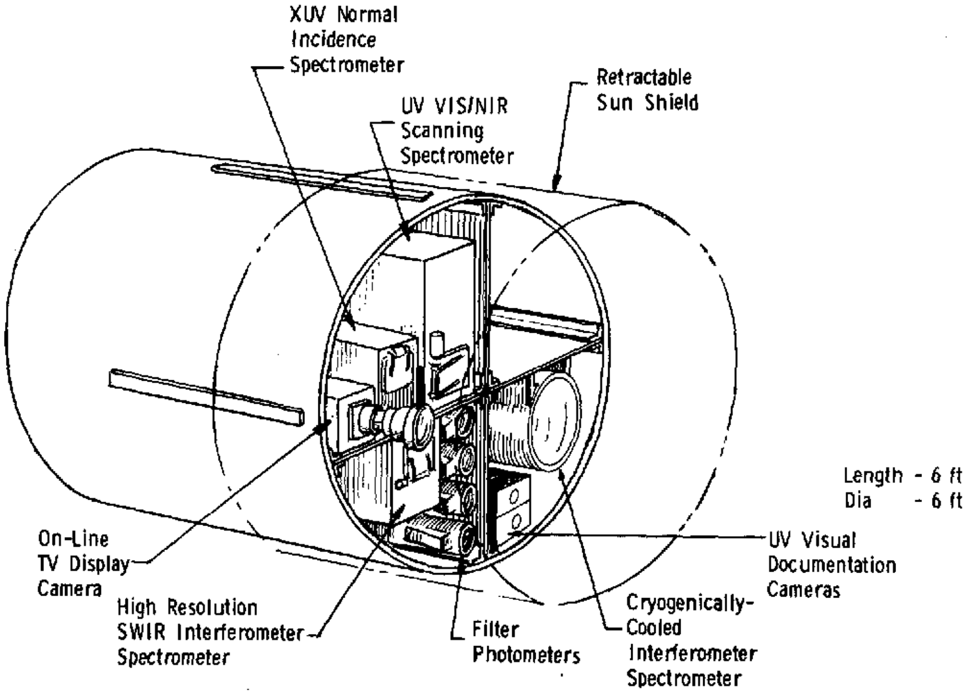
The instruments and configuration of the Solar Monitor cluster are shown in Figure 3.2-4. A solar tracker automatically acquires and tracks the sun when it is visible. The cluster is programmed to scan the solar disk in selectable patterns.

The Previewer (see Figure 3.2-5) is a separate independently pointable cluster which enables the ASF operator to observe upcoming targets and search for transient phenomena without interfering with MIC measurements. Outputs of the Previewer are displayed to the operator. Previewer pointing is under operator control with a joystick or direct computer control.

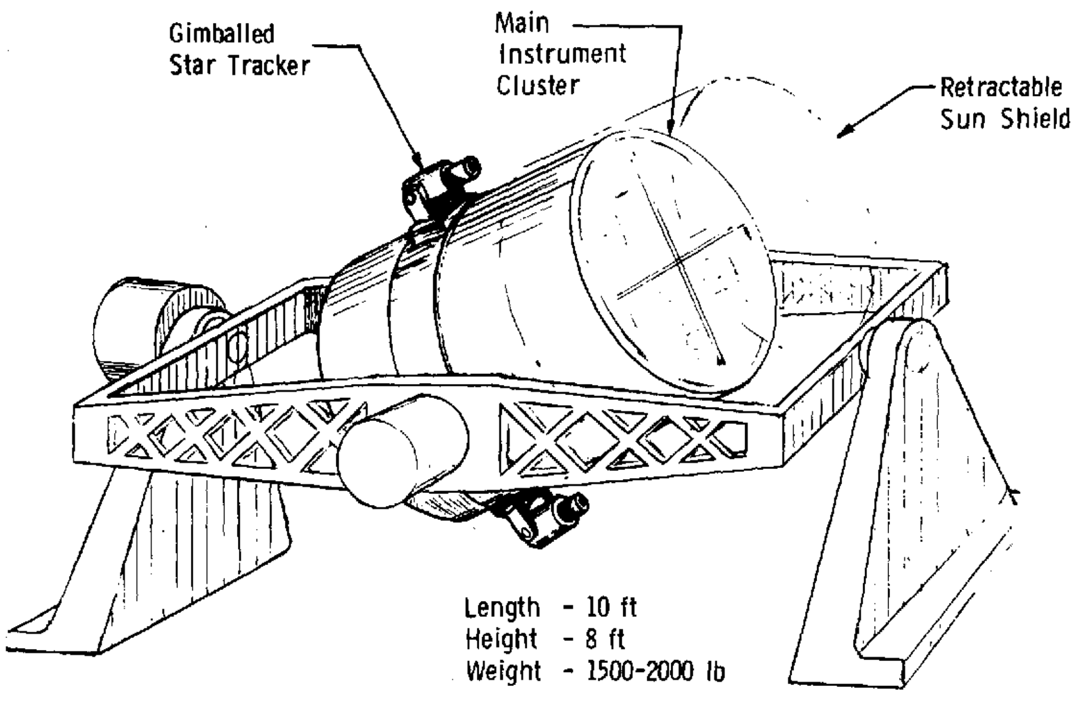
Table 3.2-1

MIC Pointing and Control Performance Requirements

• Absolute Pointing	3 arc min
• Relative Pointing	20 arc sec
• Stability	2 arc sec
• Scan Rates	Up to 5°/sec
• Scan Types	Raster
	Horizontal
	Vertical
• Gimbal Limits	
Outer	±90°
Middle	±70°
Roll	360°



a. MIC Instruments



b. MIC Gimbal Mount Configuration

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Figure 3.2-3 Main Instrument Cluster

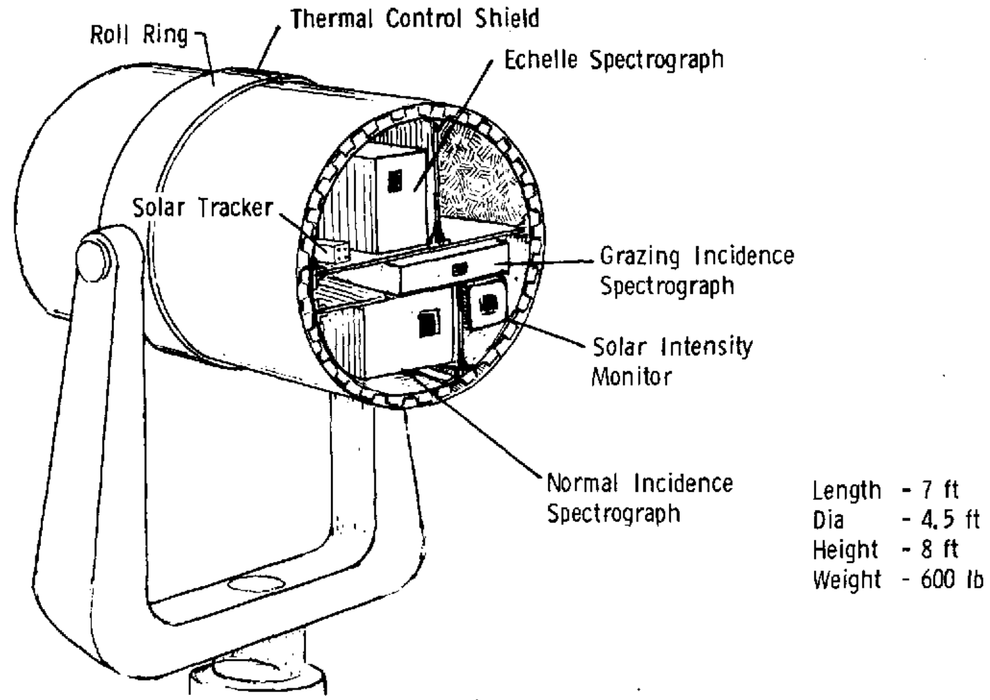

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Figure 3.2-4 Solar Monitor Instrument Cluster

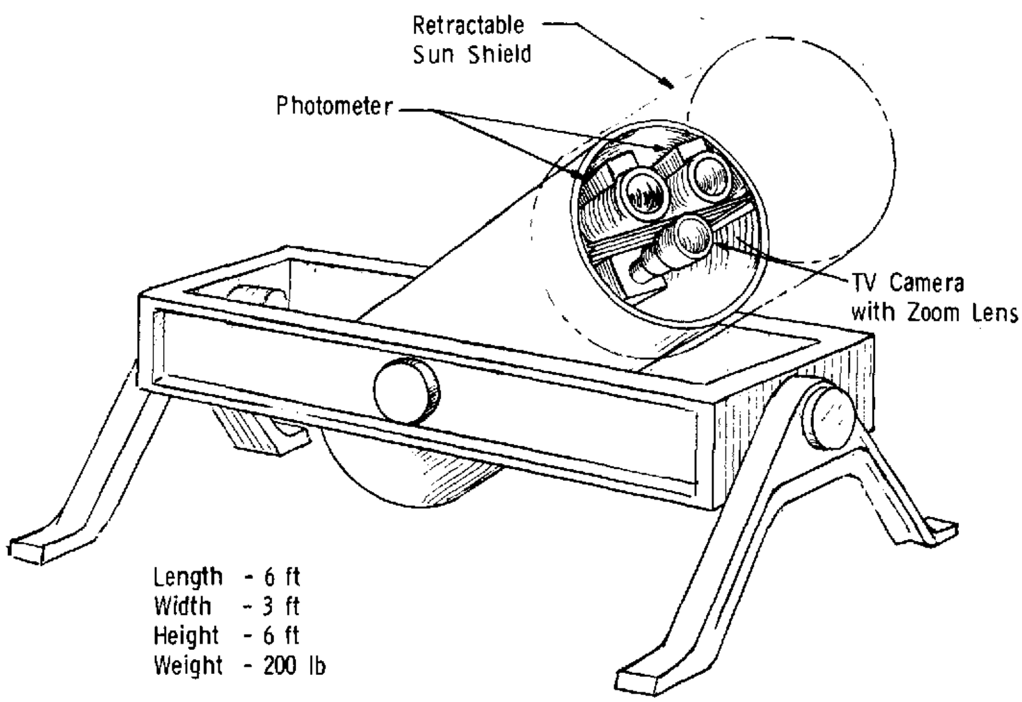

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Figure 3.2-5 Previewer Instrument Cluster

3.2.2 ASF Instruments

Atmospheric Science Facility instruments are grouped into the three clusters described in Section 3.2.1.

3.2.2.1 Main Instrument Cluster Instruments

The MIC contains the following instruments:

- XUV Normal Incidence Spectrometer.
- UV-VIS/NIR Scanning Spectrometer.
- High-Resolution SWIR Interferometer Spectrometer.
- Cryogenically Cooled Interferometer Spectrometer.
- Filter Photometer (four units).
- UV Visual Documentation Cameras (two units).
- On-Line TV Display Camera.

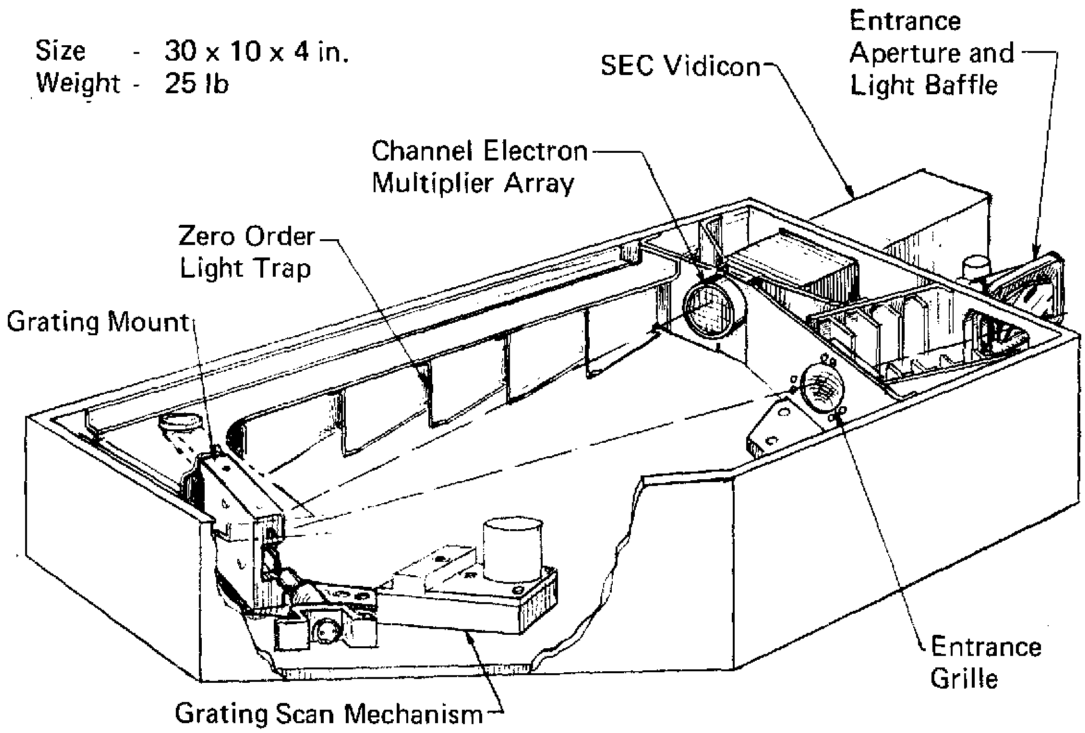
Each of these instruments is described in the following paragraphs.

<u>XUV Normal Incidence Spectrometer</u> - The instrument characteristics are summarized in Table 3.2-2 and preliminary configuration and electronics shown in Figure 3.2-6.

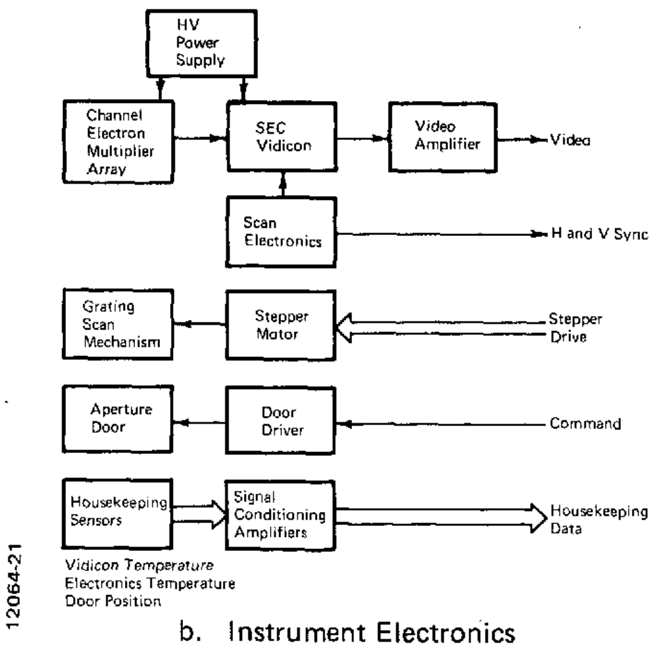
Table 3.2-2

XUV Normal Incidence Spectrometer Characteristics

Parameter	Requirement
Wavelength Range	300 to 1,300 Å
Sensitivity	0.1 Rayleighs (R) at 584 Å (1 sec integration time)
Dynamic Range	0.1 to 2,000
Signal/Noise Ratio	$\geq$ 4 (for minimum signal)
Spectral Resolution	$\Delta\lambda$ = 10 Å



a. Instrument Configuration



b. Instrument Electronics

Figure 3.2-6 XUV Normal Incidence Spectrometer

Table 3.2-2 (Cont.)

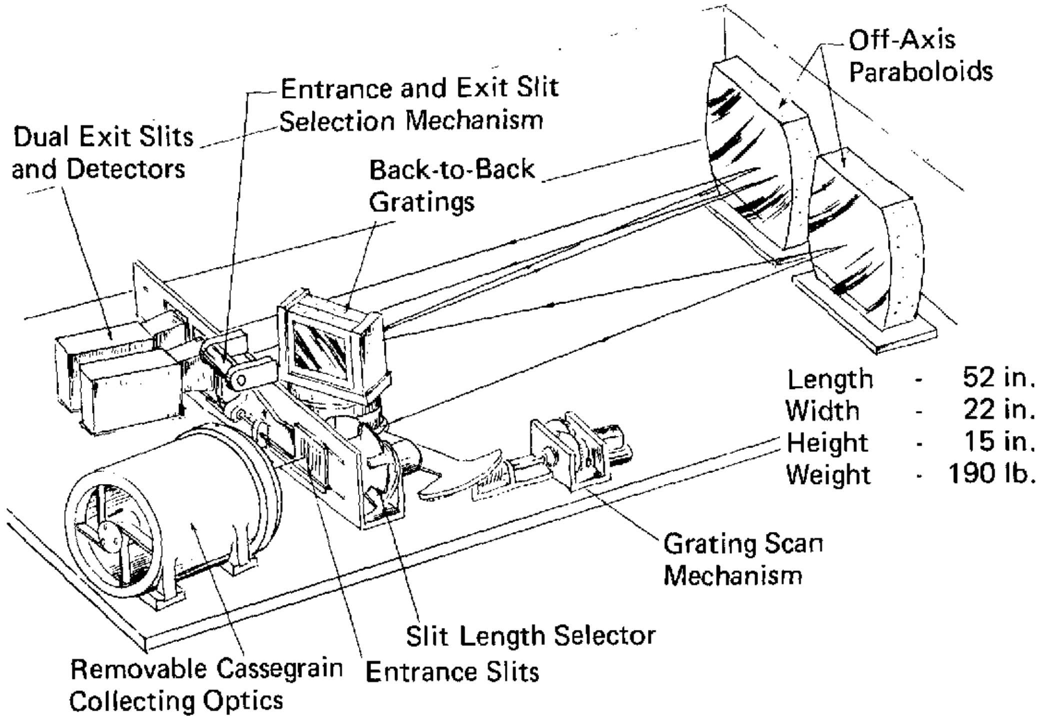
Parameter	Requirement
Spectral Purity	$\leq$ 25% (for minimum signal)
Polarization	Instrument response to polarized light should be measured
Calibration	Orbital calibration check using solar radiation
Scan Rate	One complete scan in $\leq$ 2 min
Field of View	10° full width
Off-Axis Rejection	10^{-4} at 15° off instrument axis

UV-VIS/NIR Scanning Spectrometer - The instrument performance requirements are summarized in Table 3.2-3 and preliminary configuration and electronics shown in Figure 3.2-7.

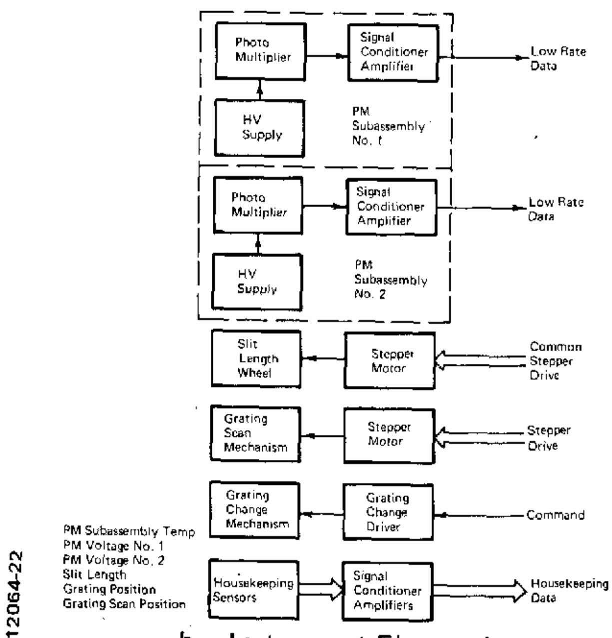
Table 3.2-3

UV-VIS/NIR Spectrometer Performance Requirements

Parameter	Requirement
Wavelength Range	1,150 Å - 1.1 μm
Wavelength Resolution	0.1 Å for λ < 3,000 Å
	0.3 Å for λ > 3,000 Å
Wavelength Precision	0.1 Å for λ < 3,000 Å
	0.3 Å for λ > 3,000 Å
Sensitivity	0.1 R (1 sec integration time)
Dynamic Range	0.1 R to 10^9 R
Radiometric Precision	± 10% Relative



a. Instrument Configuration



b. Instrument Electronics

Figure 3.2-7 UV-Visible/NIR Scanning Spectrometer

Table 3.2-3 (Cont.)

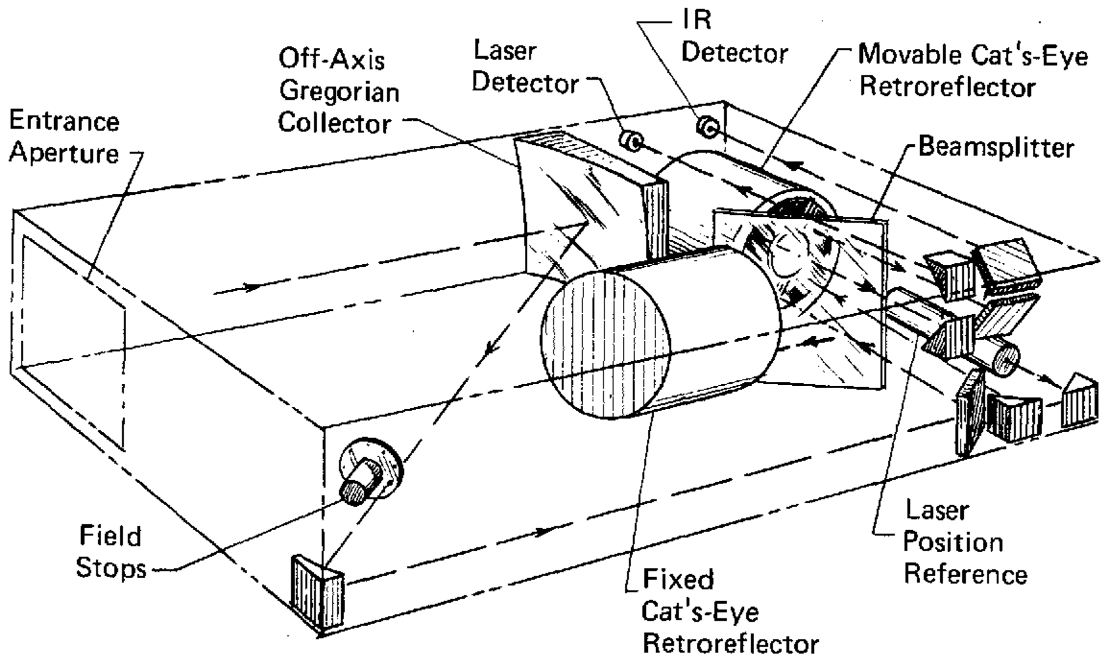
Parameter	Requirement
Field of View	0.08 x 1.8 mrad to 12 x 44 mrad
Polarimetric Precision	
Fractional Polarization	± 0.1%
Other Stokes Parameters	± 5%
Spectrum Scan Time at Highest Resolution	40 sec
Off-Axis Light Rejection	10^8 at 30 arc min outside of nominal FOV
Spectral Purity	< 1% contamination from wavelengths outside nominal passband

High Resolution SWIR Interferometer Spectrometer - The instrument characteristics are summarized in Table 3.2-4 and preliminary configuration and electronics shown in Figure 3.2-8.

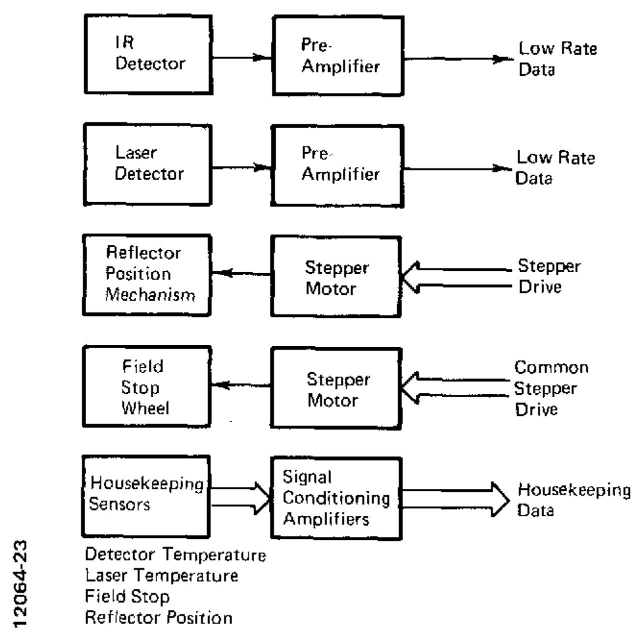
Table 3.2-4

High Resolution SWIR Interferometer Spectrometer Performance Requirements

Parameter	Requirement
Wavelength Range	1 to 5 μm
Sensitivity	10^{-11} W cm^{-2} sr^{-1} μm^{-1} (at 5 cm^{-1} resolution)
Signal/Noise Ratio	100/1 (for analytic spectroscopy)
Dynamic Range	10^6
Spectral Resolution	0.05 cm^{-1} (max)



a. Instrument Configuration



b. Instrument Electronics

Figure 3.2-8 High Resolution SWIR Interferometer Spectrometer

Table 3.2-4 (Cont.)

Parameter	Requirement
Observation Time	$\leq$ 3 min
Field of View	Selectable on command, 3, 5, 15, and 30 arc min and 1° and 5°
Off-Axis Rejection	10^6 minimum

Cryogenically Cooled Interferometer Spectrometer - The instrument characteristics are summarized in Table 3.2-5, and the preliminary configuration and electronics are shown in Figure 3.2-9. The instrument acquires data in the 5 to 150-μm spectral region in three discrete intervals with interchangeable filter/beamsplitter/detector combinations. These components would be mounted before launch and be fixed for the mission duration.

Table 3.2-5

Cryogenically Cooled Interferometer Spectrometer
Performance Requirements

Parameter	Requirement Configuration A	Configuration B	Configuration C
Wavelength	5 to 15 μm	15 to 50 μm	50 to 150 μm
Sensitivity (at 5 cm^{-1} resolution)	10^{-11} W cm^{-2} sr^{-1} μm^{-1}	10^{-11} W cm^{-2} sr^{-1} μm^{-1}	10^{-11} W cm^{-2} sr^{-1} μm^{-1}
Signal/Noise Ratio	100/1	TBD	TBD
Dynamic Range	10^5	10^5	10^5
Spectral Resolution (max)	0.1 cm^{-1}	0.1 cm^{-1}	0.1 cm^{-1}
Observation Time	$\leq$ 3 min		
Field of View	Selectable on command, 3, 5, 15, and 30 arc min and 1° and 5°		
Off-Axis Rejection	10^6 - 10^7 (30 arc min outside nominal FOV)		

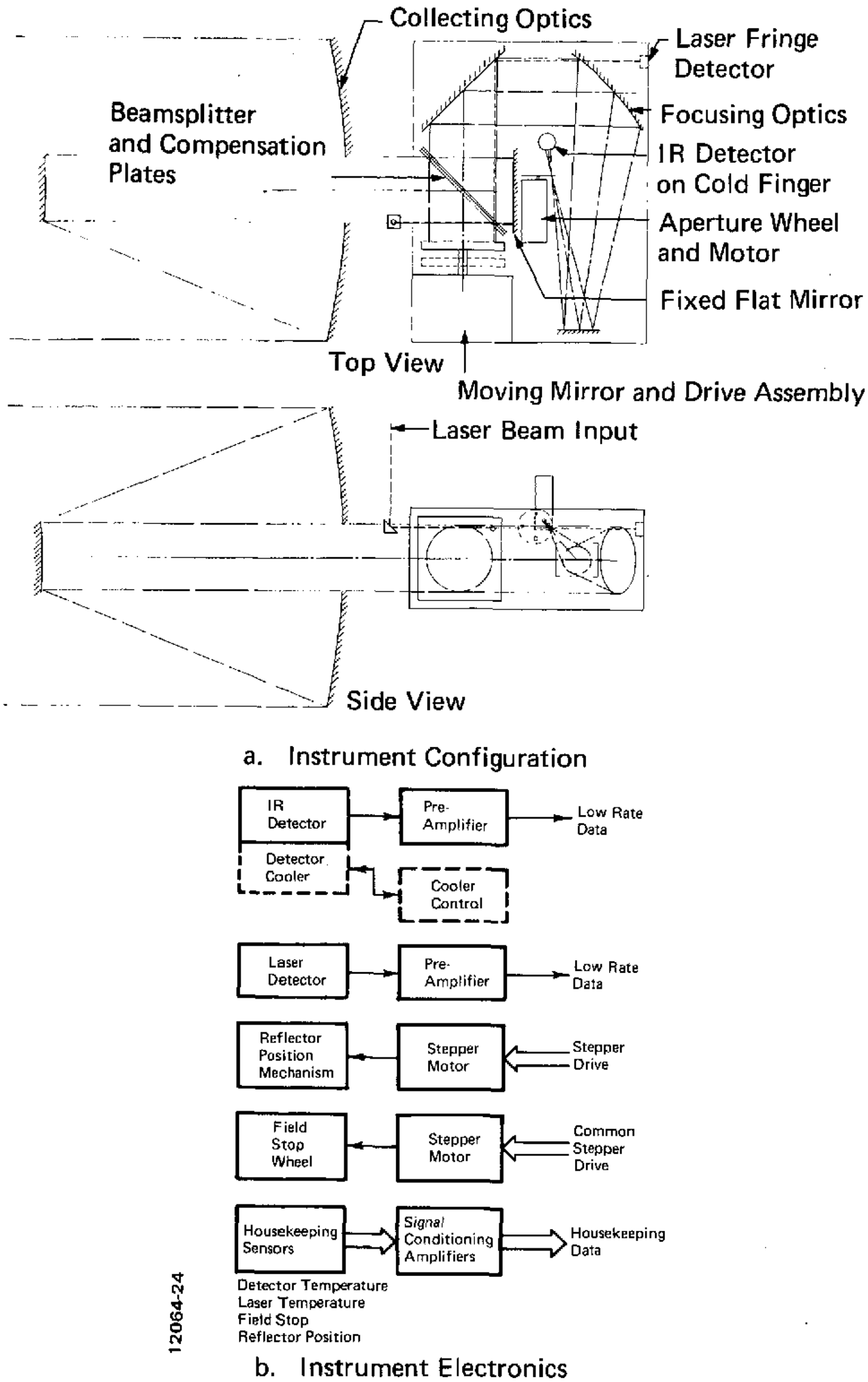


Figure 3.2-9 Cryogenically Cooled Interferometer Spectrometer

Filter Photometer - The instrument characteristics are summarized in Table 3.2-6, and the preliminary configuration and electronics are shown in Figure 3.2-10.

Table 3.2-6

Filter Photometer Performance Requirements

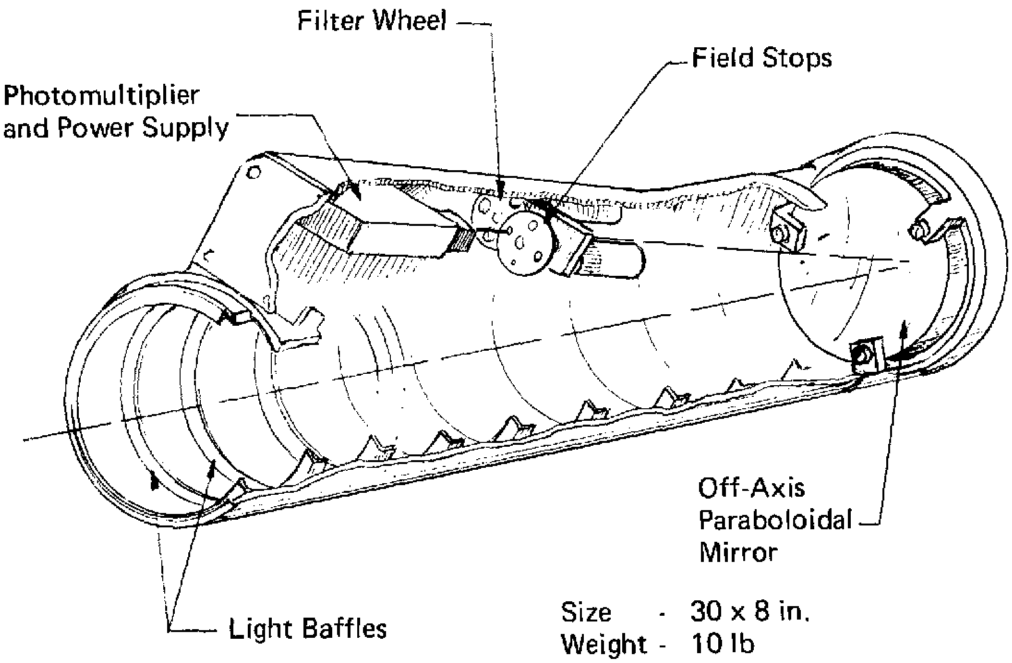
Parameter	Requirement
Wavelength Range	Discrete bands between 1,050 and 8,000 Å
Sensitivity	0.1 R (at SNR = 1 and observation times of 1 msec)
Spectral Resolution	15 Å filter passband
Observation Time	$\geq$ 1 msec
Field of View	Adjustable from 1 arc min to 1°
Radiometric Accuracy	± 5% relative
Off-Axis Light Rejection	10^6 (at 10 arc/min outside nominal FOV)

UV-Visual Documentation Camera - The instrument characteristics are summarized in Table 3.2-7, and the preliminary configuration and electronics are shown in Figure 3.2-11.

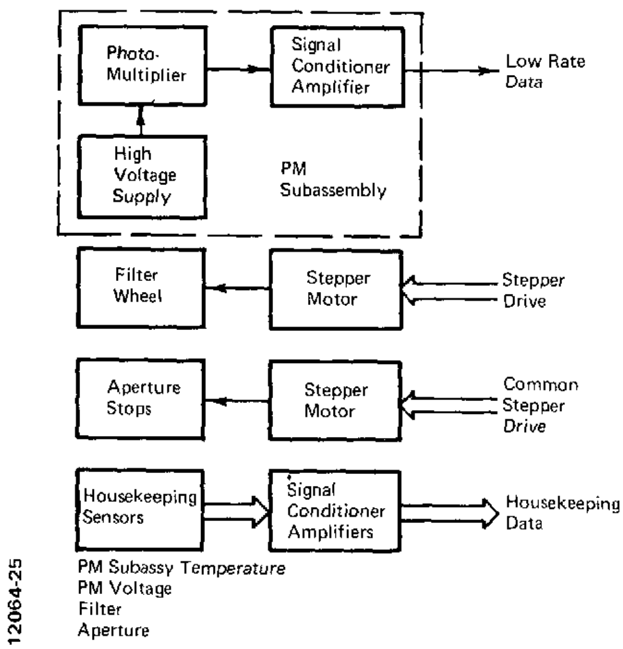
Table 3.2-7

UV-Visual Documentation Camera Performance Requirements

Parameter	Requirement
Two 35-mm Cameras	
Wavelength Range	UV - 2,400 to 7,000 Å Visible - 3,500 to 7,000 Å
Wavelength Resolution	Filters (±250 Å)
Field of View	≈30°
Number of Exposures	Up to 800 (at five per second)

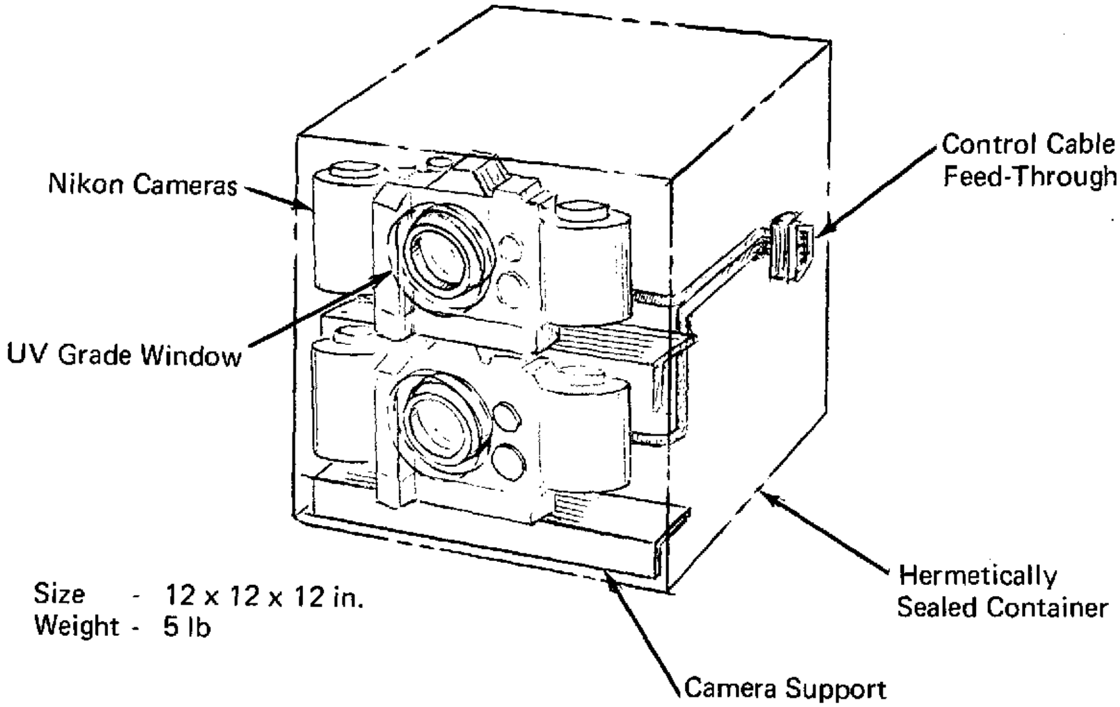


a. Instrument Configuration

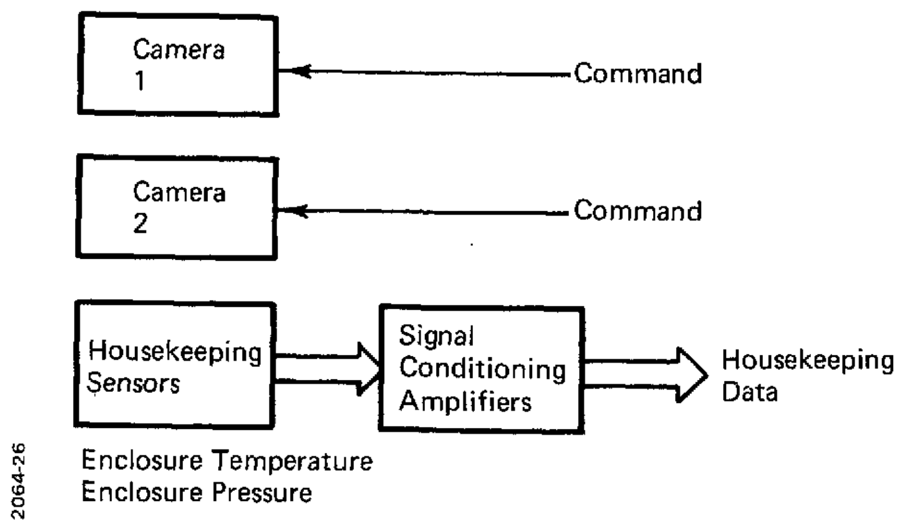


b. Instrument Electronics

Figure 3.2-10 Filter Photometer



a. Instrument Configuration



b. Instrument Electronics

Figure 3.2-11 UV-Visual Documentation Camera

On-Line TV Display Camera - The on-line TV display camera consists of a TV camera with zoom lens and remote control. The camera characteristics are summarized in Table 3.2-8, and the electronics are shown in Figure 3.2-12.

Table 3.2-8

On-Line TV Display Camera Performance Requirements

Parameter	Requirement
Wavelength Response	S-20
Field of View	2 to 20° (continuous)
Angular Resolution	1 arc min
Signal/Noise Ratio	32 dB (at 3 ft-L)
Gray Scale	64 levels, 6 bits

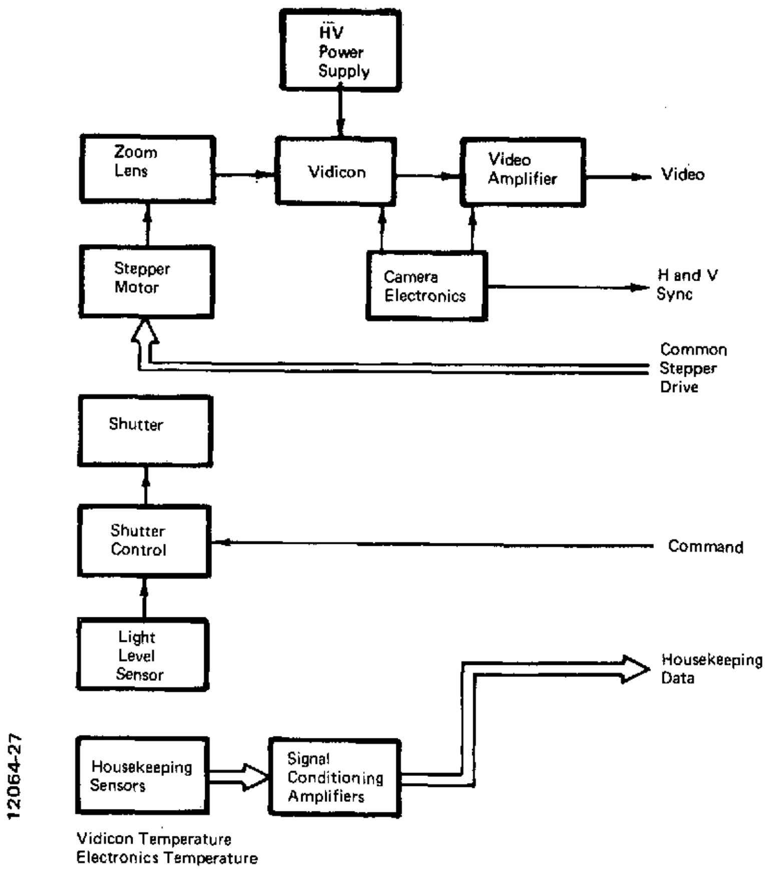


Figure 3.2-12 On-Line TV Display Camera Electronics

3.2.2.2 Solar Monitor Instruments

The Solar Monitor contains the following instruments:

- High Spectral Resolution Line Profile Spectrographs.
- Solar XUV-UV Intensity Monitor.

These instruments are described in the following paragraphs.

High Spectral Resolution Line Profile Spectrographs – The instrument characteristics are summarized in Table 3.2-9. Three spectrographs are required to cover the spectral range desired: a grazing-incidence spectrograph for 300 to 600 Å; a normal-incidence spectrograph for 580 to 1,220 Å; and an Eschelle spectrograph for 1,150 to 1,800 Å. The preliminary instrument configurations are shown in Figure 3.2-13 and the electronics in Figure 3.2-14.

Table 3.2-9

High Spectral Resolution Line Profile Spectrograph Performance Requirements

Parameter	Requirement
Wavelength	300 to 600 Å; 580 to 1,220 Å; 1,150 to 1,800 Å
Sensitivity	Optimize with respect to background signal level from scattered light; determined by detector
Dynamic Range	Determined by detector; may be varied with mission depending on solar lines to be observed
Spectral Resolution	$\Delta\lambda$ = 0.02 Å
Polarization	Instrument response to polarized light should be measured
Calibration	Ground calibration only
Observation Time	$\leq$ 5 min (time to record spectrum varies with instrument design, wavelength range, detector choice)
Field of View	Determined by limitations of optical system; spectra of full solar disk would be obtained by scanning instrument.

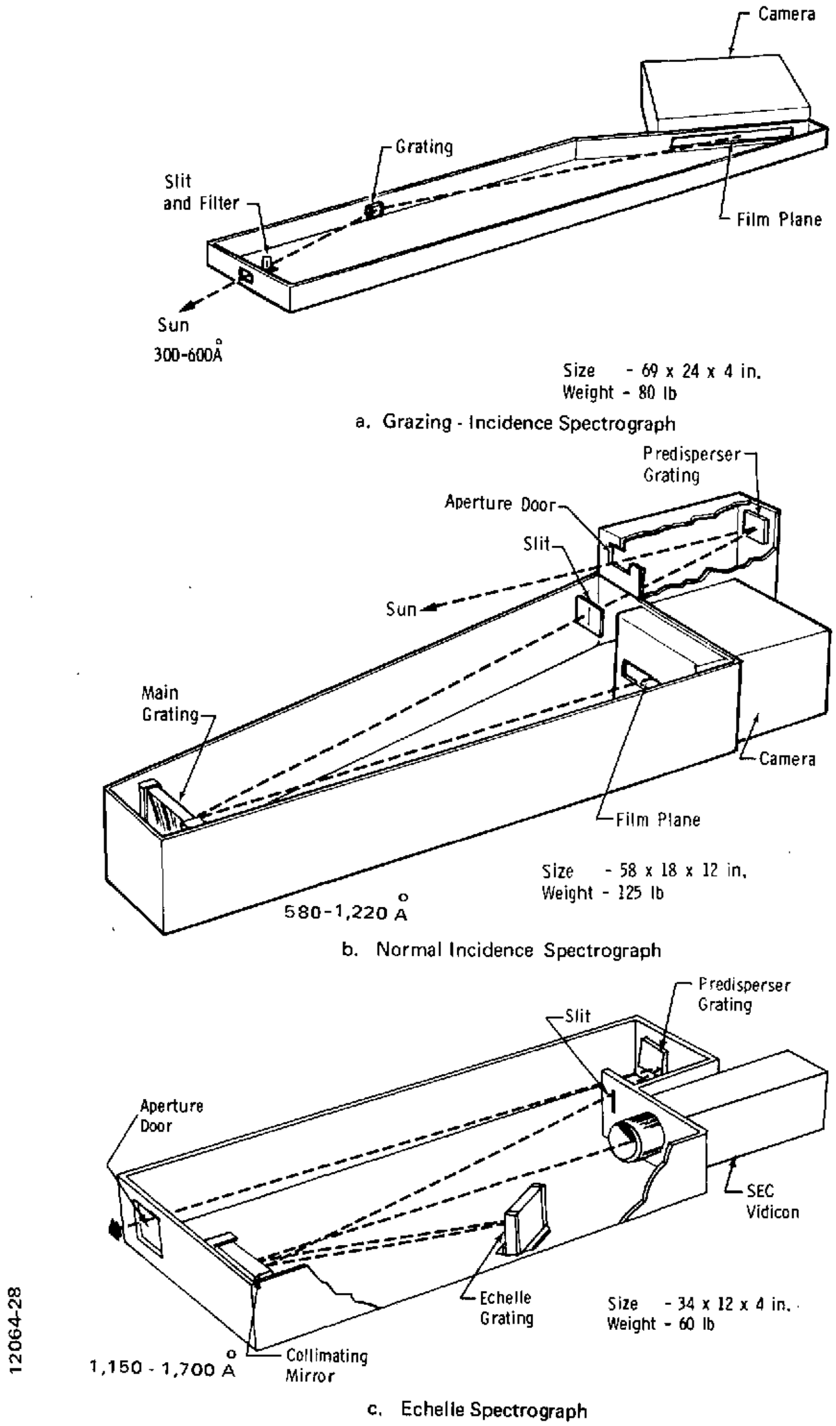


Figure 3. 2-13 High Spectral Resolution Line Profile Spectrographs

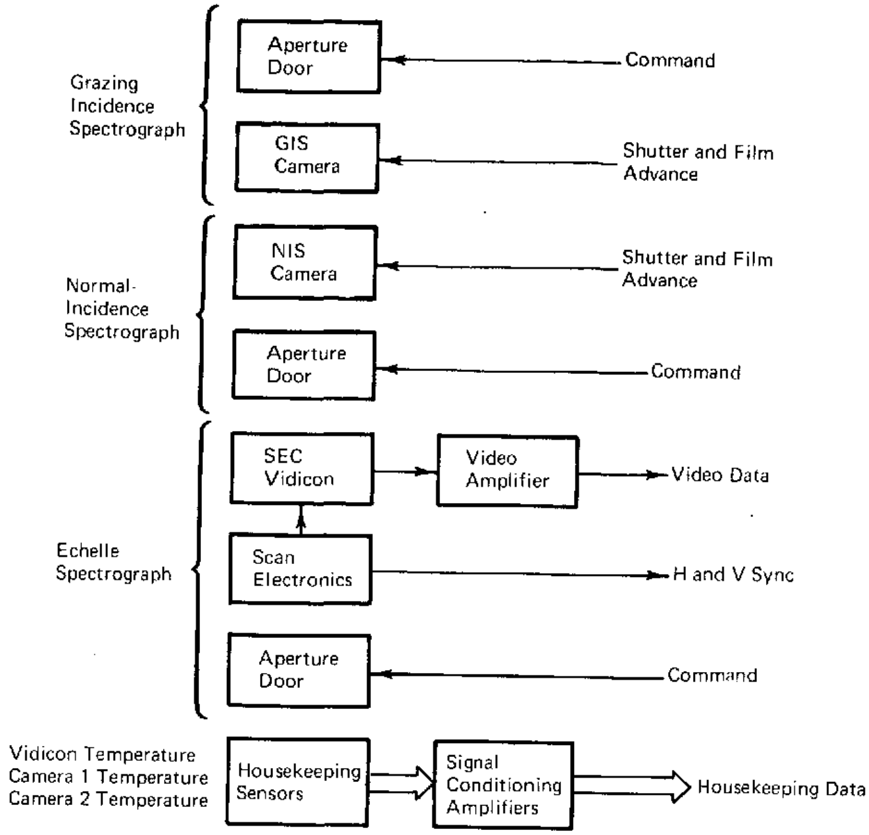


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Figure 3.2-14 High Spectral Resolution Line Profile

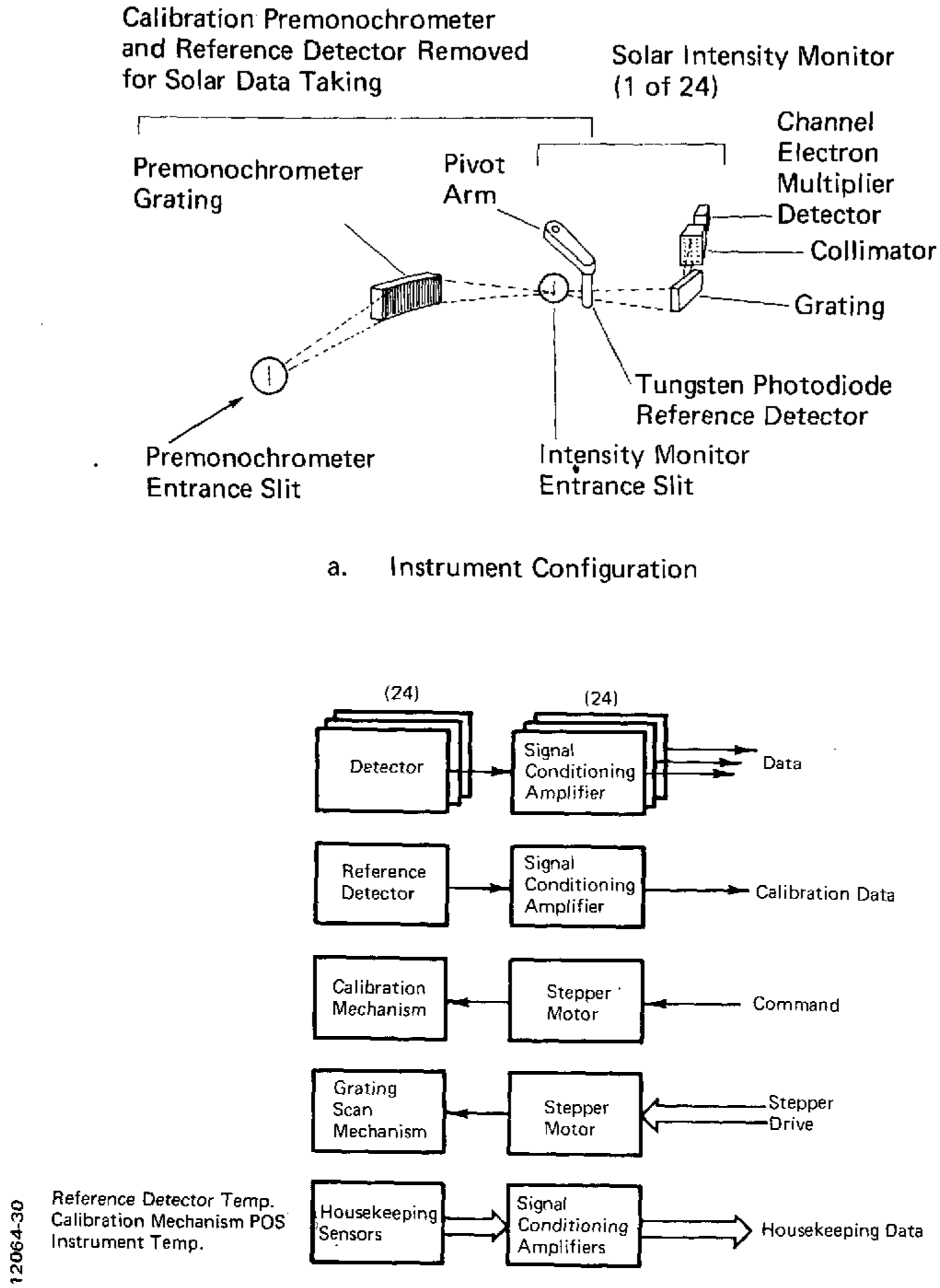
Solar XUV-UV Insensity Monitor – The instrument characteristics are summarized in Table 3.2-10. A set of monochrometers optimized to each part of the wavelength range is required. A set of fixed wavelength monochrometers monitor principal solar lines, and a set with each unit scanning a small portion of the wavelength band provides coverage of all lines in the band. Figure 3.2-15a shows the monochrometer and orbital calibration scheme; Figure 3.2-15b shows the instrument electronics.

3.2.2.3 Previewer Instruments

The Previewer contains the following instruments:

- TV Camera with Zoom Lens.
- Filter Photometers (two units).

These instruments are identical to the TV camera and Photometers described in Section 3.2.2.1 and contained in the Main Instrument Cluster.



a. Instrument Configuration

b. Instrument Electronics

Figure 3.2-15 Solar XUV-UV Intensity Monitor

Table 3.2-10

Solar XUV-UV Intensity Monitor Performance Requirements

Parameter	Requirement
Wavelength Range	180 - 1,800 Å
Sensitivity	1% relative accuracy in 0.25 sec
Dynamic Range	L α, 270 x 10^9 photons cm^{-2} sec^{-1} Ne VIII (780 Å), 0.15 x 10^9 photons cm^{-2} sec^{-1}
Spectral Resolution	$\Delta\lambda \approx 2$ Å
Spectral Purity	< 2% of radiation out of band
Polarization	Instrument response to polarized light should be known
Calibration	$\leq$5% absolute (orbital calibration uses pre-monochrometer and reference detector)
Observation Time	10 min full scan
Field of View	7 arc min (along dispersion direction), 32 arc min (normal to dispersion direction)

3.2.3 Instrument Data and Command Requirements

The basic instrument data and command requirements, summarized in Table 3.2-11, are those data samples and commands which must be executed at a precisely regular interval. In addition to the tabulated requirements, there are housekeeping data to be acquired and discrete functions to be performed such as opening or closing an aperture.

Overall, the instruments contain four video-rate data sources, 32 low-rate data sources, and 37 identified housekeeping data sources. The housekeeping sources probably would grow in number; provision should be made for at least 64.

Table 3.2-11

Instrument Data and Command Rates

Instrument	Data Rate	Grating Scan Rate	Command Rate
Main Instrument Cluster			
XUV Normal Incidence Spectrometer	TV Video	1 Step/Sec	——
UV-VIS/NIR Scanning Spectrometer	1K Sample/Sec	500 Steps/Sec	——
High Res SWIR Interferometer Spectrometer	890 Sample/Sec	890 Steps/Sec	——
Cryogenically Cooled Interferometer Spectrometer	890 Sample/Sec	890 Steps/Sec	——
Filter Photometers (2)	2K Sample/Sec	——	——
UV-Visual Documentation Cameras	——	——	5/sec
On-Line TV	TV Video	——	——
Solar Monitor			
Grazing Incidence Spectrograph	——	——	1/min
Normal Incidence Spectrograph	——	——	1/min
Eschelle Spectrograph	TV Video	——	——
Solar XUV-UV Intensity Monitor	825 Sample/Sec	81 Steps/Sec	——
Previewer			
TV Camera	TV Video	——	——
Filter Photometers (2)	2K Sample/Sec	——	——

The total command requirement identified is 25 discrete commands, six stepper motor drives which must operate concurrently, and eight stepper motor drives which operate asynchronously and non-overlapping times. The total command requirement is also likely to grow as the instrument definition progresses.

3.2.4 NIM-CAMAC Applicability to ASF

A CAMAC implementation is possible which would provide all data collection, command, and control for all ASF sensors, instruments, and gimbal drives with the exception of data collection for the TV camera and video rate spectrometers.

Some functions could be performed with NIM modules, but the same functions are available in CAMAC and there is no advantage and considerable disadvantage to mixing NIM and CAMAC unless necessary.

Although it is possible to use CAMAC modules for most ASF supporting electronics, the following factors lead to a design using a combination of special design-dedicated electronics and CAMAC modules:

- The ASF pointing mounts and instrument carriers have general application to other sensors which require pointing in Shuttle Sortie missions; for example, Earth Resources sensors.
- Each instrument cluster must have flexible support capabilities to permit easy change of the instrument payload.
- Cables to the instrument mounts must be minimized to permit freedom of movement.
- Cables into the Sortie Lab pressurized module must be minimized and cannot be readily changed in number and type.
- NIM and CAMAC equipment must be located in a pressurized area to provide an atmosphere for cooling the modules.
- Long cable runs from the Sortie Lab to the instrument clusters dictate that all sensor outputs be through a signal conditioning amplifier and actuator drive amplifiers to be located near each actuator.

The approach to using CAMAC for the ASF while accomodating the above listed factors is described in Section 3.2.5.

3.2.5 Facility Description

The Atmospheric Science Facility (ASF) electronics described in this section are designed to provide the data collection, pointing, command, and control of the instruments described in Section 3.2.2. The ASF configuration described uses a combination of CAMAC modules and special design electronics as dictated by the applicability factors defined in Section 3.2.4. Figure 3.2-16 shows the block diagrams of the resulting ASF instrument support electronics.

The implementation shown in Figure 3.2-16 has two main features which govern the extent to which CAMAC has been used. The first is the use of two CAMAC-computer systems, one for pointing control and the other for instrument operations. The second feature is the use of common data multiplex and command decoder electronics dedicated to each instrument cluster. This feature permits a minimum of cables between the Sortie Lab and each gimbaled instrument mount and permits flexibility in instrument complement without changing the cabling interface.

In the system shown the three instrument clusters are pointed under control of the pointing computer or the operator via a joystick controller in the video display and pointing control unit. The pointing computer obtains shuttle orbit, altitude, and attitude data from the shuttle guidance computer.

The three instrument clusters are interfaced for command and data acquisition to the experiment computer via the instrument cluster common electronics and CAMAC equipment. A block diagram of one set of common electronics is shown in Figure 3.2-17. All data except the video signals are transmitted between the common electronics and the CAMAC electronics in digital form. Data and commands are transmitted as differential signals to minimize noise problems. All data except video are multiplexed in the common electronics to minimize cables. Similarly, all commands are multiplexed. Individual stepper motor drives are provided for components requiring continuous drive, such as the spectrometer gratings. A common stepper motor drive is provided which is directed by command to the desired component for drives used infrequently, asynchronously, and non-overlapping with each other; e.g., aperture door controls.

CAMAC crates are used to provide, with special microprogrammed crate controllers, independence of operation between the "busy" main instrument cluster and the other two clusters. The CAMAC module complement of these crates is tabulated in Table 3.2-12.

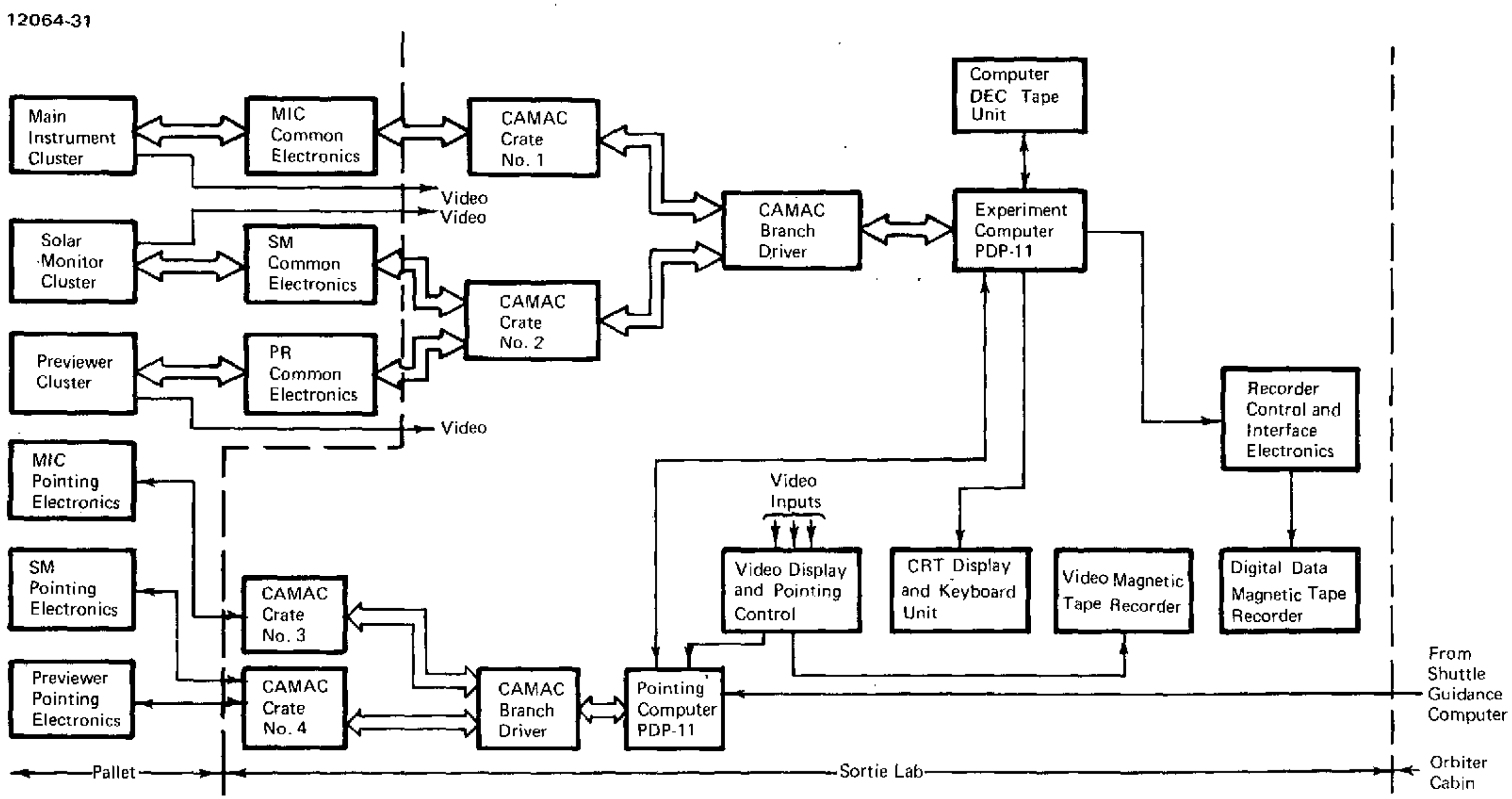


Figure 3.2-16 ASF Instrument Support Electronics

Table 3.2-12

CAMAC Modules Used in ASF

CAMAC Module	Weight (kg)	Power (W)	Cost ($)
Branch Driver (2) BD-011[a]	22.8	120	9,600
Crate No. 1			
Powered Crate MC100[a]	22.7	130	1,545
Programmable Controller[b]			
Interrupt Register IR026[a]	0.8	2.3	395
Differential Input Register 3430[c]	0.5	3.6	455
Differential Output Register 3030[c]	0.5	4.8	430
Stepper Motor Controller (6) 3361[c]	6.0	60.0	4,350
Real-Time Clock RC014[a]	0.8	4.3	595
Crate No. 2			
Powered Crate MC100[a]	22.7	130	1,545
Programmable Controller[b]			
Terminator BT-01[c]	0.1	1.8	295
Interrupt Register IR026[a]	0.8	2.3	395
Differential Input Register (2) 3430[c]	1.0	7.2	910
Differential Output Register (2) 3030[c]	1.0	9.9	860
Stepper Motor Controller (3) 3361[c]	3.0	30.0	2,175
Real-Time Clock RC014[a]	0.8	4.3	595
Crate No. 3			
Powered Crate MC100[a]	22.7	130	1,545
Programmable Controller[b]			
Differential Input Register (2) 3430[c]	1.0	7.2	910
Differential Output Register (9) 3030[c]	4.5	43.2	3,870
Position Encoder (5) PE019[a]	4.0	33.0	3,950
Interrupt Register IR026[a]	0.8	2.3	395
Crate No. 4			
Powered Crate MC100[a]	22.7	130	1,545
Programmable Controller[b]			
Terminator BT-01[c]	0.1	1.8	295
Differential Input Register (2) 3430[c]	1.0	7.2	910
Differential Output Register (6) 3030[c]	3.0	28.8	2,580
Position Encoder (3) PE019[a]	2.4	19.8	2,370
32 Channel Analog Data 5301[d]	1.0	8.0	1,500
Interrupt Register IR026[a]	0.8	2.3	395

( ) Numbers in parentheses refer to number of modules.

(a) Manufactured by EG&G/Ortec.

(b) Programmable Controllers are under development. Manufacturer, weight, power, and cost are not available. A Type "A" controller could be used at a lower speed of operation.

(c) Manufactured by Kinetic Systems.

(d) Manufactured by Bi Ra Systems.

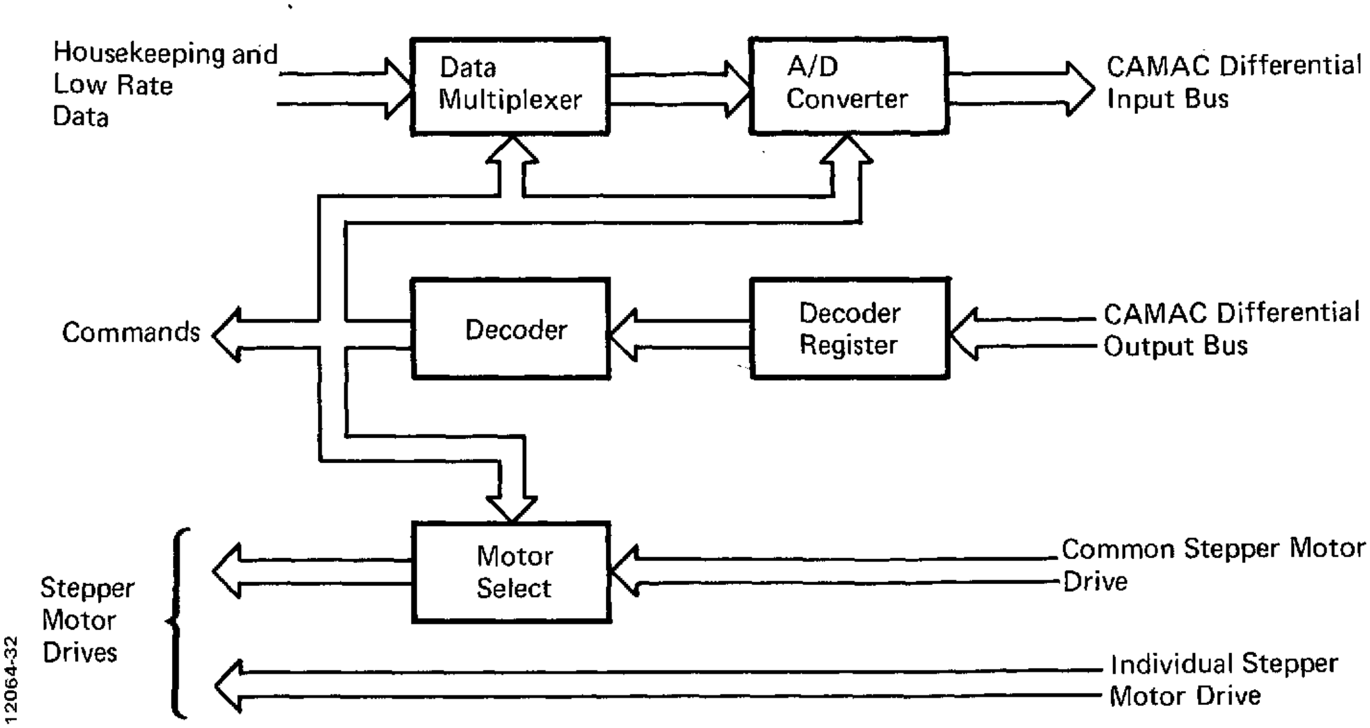


Figure 3.2-17 Instrument Cluster Common Electronics

The special microprogrammed crate controller, although not available today, will most certainly be available in the ASF time frame. It is based on the new microprocessor integrated circuit chips and contains enough memory to permit the controller to be microprogrammed by the experiment computer for each experiment configuration and experiment mode. With this controller much of the burden of instrument command and control is taken over by the controller from the experiment computer, leaving the latter free for data formatting and control operations.

The computer DEC tape unit is provided for basic program storage.

Operator control and interaction is through the video display and pointing control unit and the CRT display and keyboard unit. The video display outputs video data from the TV cameras, and the CRT display outputs status, housekeeping, and selected data in alphanumeric format.

All video data are recorded directly on video magnetic tape; all digital data are recorded on a multitrack digital magnetic tape.

Figure 3.2-18 shows a sketch of the support electronics configuration. All units are rack-mounted; operate from 110 volts, 60 cycles; and require forced air cooling. Fans for cooling air circulation have not been shown nor have their weight and power been included in Table 3.2-13, which summarizes the electronics weight and power requirements.

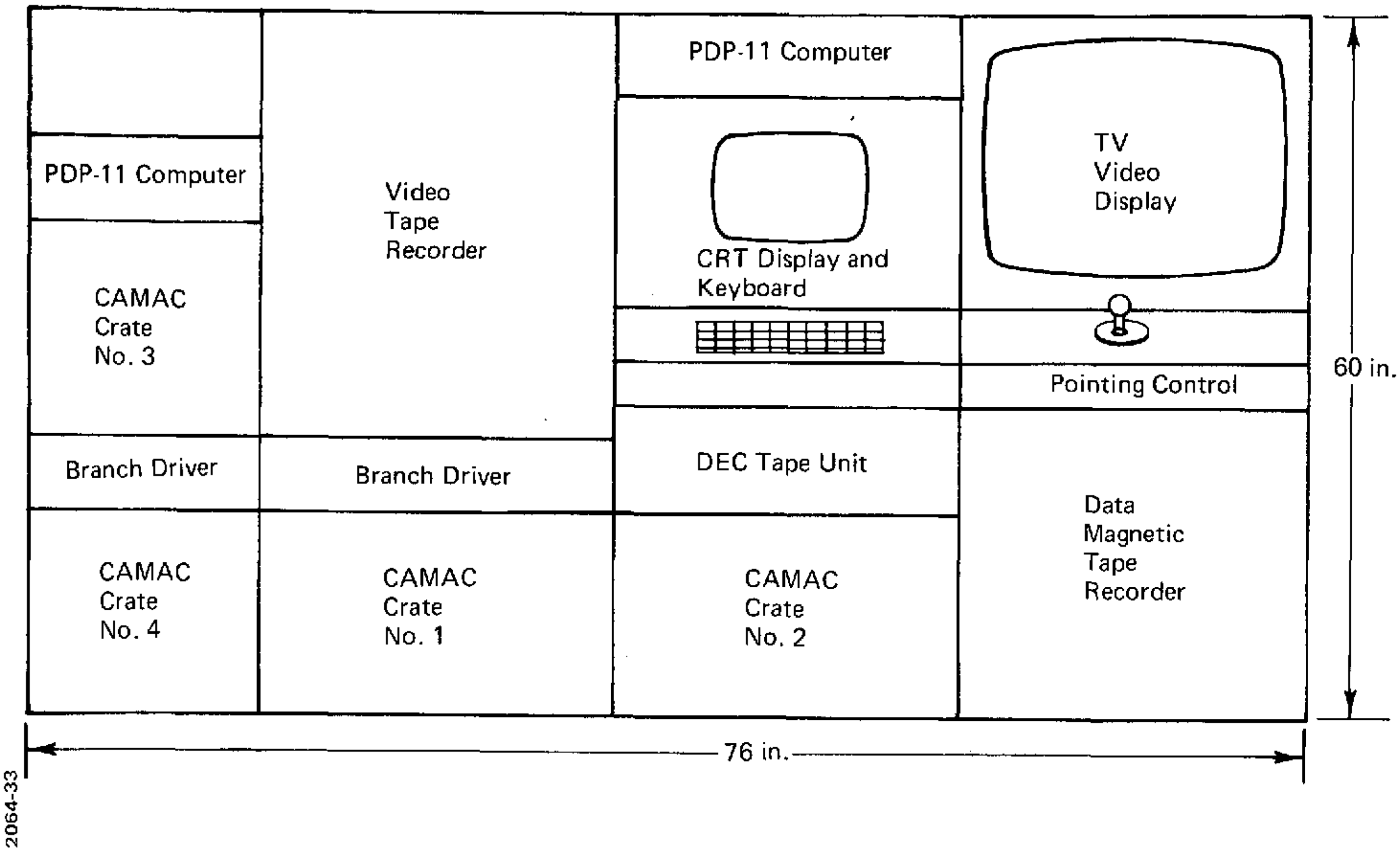


Figure 3.2-18 ASF Instrument Support Electronics Configuration

3.2.6 References

1. Report of the Atmospheric and Space Physics Working Group, Woods Hole Summer Study, July 1973.

2. Background Information for Atmospheric, Magnetospheric, and Plasmas in Space (AMPS) Working Groups, April 1974, Marshall Space Flight Center.

3. Preliminary Design Study for an Atmospheric Science Facility, Final Report, Dec. 1972, Martin Marietta, MCR-72-322, Contract NAS-9-12255, Johnson Space Center.

4. Preliminary Concepts from Woods Hole Atmospheric and Space Physics, October 1973, Martin Co. Report.

5. Shuttle Payload Descriptions, Volume II, Sortie Payloads, October 1973, Marshall Space Flight Center.

Table 3.2-13

ASF Instrument Support Electronics Weight and Power

Component	Weight (kg)	Power (Watts)
PDP-11/35 Computer	90	150
DEC Tape and Controller	40	870[a]
Terminal - Display and Keyboard	27	130
CAMAC Crates and Electronics	124	780
Branch Driver	23	120
Video Display and Pointing Control	55	250
Video Tape Recorder	40	300
Data Recorder and Interface	35	250
Cluster Common Electronics	15	45
Total	449	2, 025

[a] Required only during program change for new instrument or mode modification.

3.3 AURORAL AND MAGNETOSPHERIC OBSERVATORY

The Auroral and Magnetospheric Observatory is conceived as a laboratory to study natural and artificial auroras and the properties of the magnetosphere.* The observatory consists of four main instrument groups: (1) optical instrumentation, (2) accelerator and gas release, (3) diagnostic instrumentation, and (4) subsatellite. The optical instrumentation is nearly the same as the atmospheric physics facility and the conclusion was reached** that these two facilities and the Plasma Physics and Environmental Perturbation Laboratory (PPEPL) be combined. The NIM-CAMAC implementation of the optical instrumentation was covered in Section 3.2; this section covers the additional NIM-CAMAC implementation of the accelerator and gas release and the diagnostic instrumentation groups. The subsatellite is a diagnostic payload where normal satellite constraints apply and is not considered a candidate for NIM-CAMAC. An artist concept for the observatory is shown in Figure 3.3-1.*** A list of the instruments and equipment is given in Table 3.3-1.

3.3.1 Accelerator and Gas Release

Two types of accelerators, one for electrons and one for ions, are used to trace magnetic field lines by injecting the electrons or ions along a field line and observing their path by optical viewing of the artificial aurora which occurs when the particles strike the upper atmosphere or by observing the echo of electrons mirroring at the magnetic conjugate point and returning to the vicinity of the space shuttle.

The two modes of operation, artificial aurora and electron echo, place two extremes on the electron accelerator. The final accelerator design has not been developed, and it may well require two different accelerators for the two modes of operation. The artificial aurora requires an intense electron beam (greater than 1 ampere) for a long duration (greater than 1 sec) in order to be acquired and viewed by both the Shuttle optical instruments and ground-based or airborne optical instruments. The electron echo is detected by sensitive electron detectors, and a beam current of 1 to 10 mA is sufficient. The pulse duration is 1 msec to allow

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*Scientific Design of a Manned Aurora and Magnetospheric Observatory System for the Shuttle Program, NASA Manned Spacecraft Center, Houston, Texas, Feb 1973.

**Summarized NASA/ESRO Payload Descriptions, NASA Marshall Space Flight Center, Huntsville, Alabama, Oct 1973.

***Proceedings of the Second Conference on Payload Interfaces with Shuttle or Tug, Sept 6 and 7, 1973, McDonnell Douglas Astronautics, MDC G4818, Long Beach, Calif.

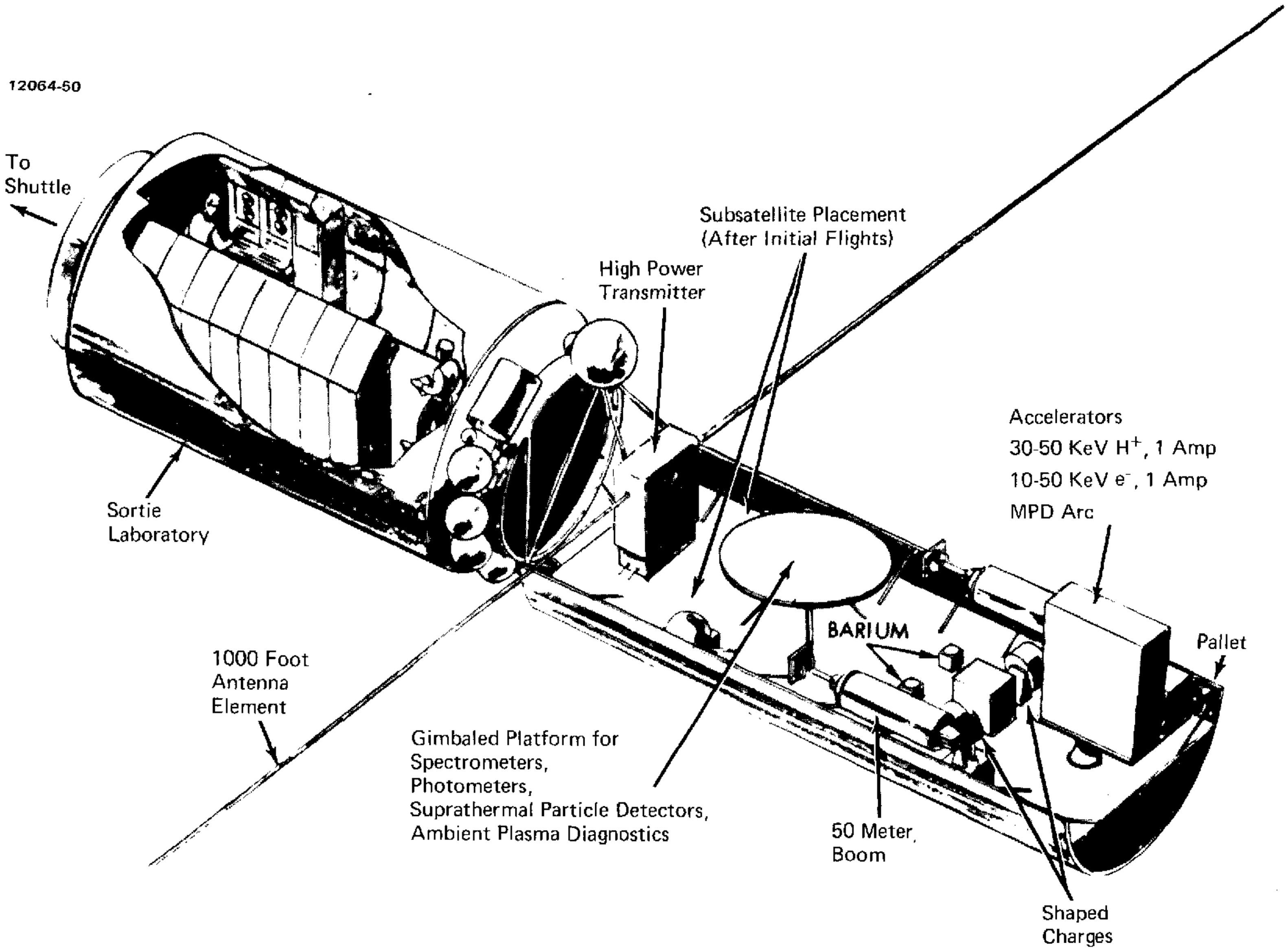

Figure 3.3-1 Aurora Magnetosphere Observatory

Table 3.3-1

Aurora and Magnetospheric Instrumentation Instruments

Accelerator and Gas Release	
Electron Accelerators	1 to 50 keV 10 mA to 1 A Pulse duration 1 msec to 5 sec
Ion Accelerators	2-8 keV at 4 to 2.5 amps Ba^+ 5 - 100 keV at 0.2 to 2.67 A H^+, He^+, and He^{++} 50 keV at 1 A, Cs^+ and Na^+
Charged Particle Detectors	Electrostatic Analyzer Solid State Detector
Gas Release	Direct Jetting Canister Release
Diagnostic	
Magnetic Field	Triaxial Fluxgate Resolution 1 gamma Accuracy - 0.1% up to 5 Hz Dynamic Range - ± 60,000
	VLF Receiver (search coils) Frequency Range - 10 Hz to 50 kHz Sensitivity 0.7 gamma
	Loop Antennas Frequency Range - 50 kHz to 25 MHz
Electric Field	Probes - spheres separated by 3 m DC and AC in filtered bands DC sensitivity - 0.1 mV/m DC accuracy - 0.5 mV/m DC dynamic range - 200 mV/m
Neutral and Ion Spectrometers	Neutral Mass Spectrometer Ion Mass Spectrometer Langmuir Probes

high time resolution, and the pulse repetition rate is less than 1/sec to 10/sec depending on echo times and observation of multiple echos. Echo times vary depending on the distance to the mirror point. For mirror points directly below the Space Shuttle, the echo times are about 10 msec; for mirror points in the sub-hemisphere, they are about 1 sec. The echo has an eastward drift of about 800 m/sec and a cross section of about 30 meters. Since the Shuttle has a velocity of about 8 km/sec, the echo can be as much as 7 km away. The Shuttle will have to have either a high inclination orbit to match the eastward drift or a subsatellite that can trail the Shuttle to be at the echo position.

To date, both types of experiments (artificial aurora and electron echo) have been carried out with rocket payloads. The electron guns were designed for the specific assignment and either one is not suitable for both modes of operation. Development of an improved electron gun to modify the artificial aurora accelerator to be dual purpose appears feasible. A single electron gun is shown in the functional block diagram of Figure 3.3-2. The high voltage power supply control varies peak voltage, pulse repetition rate, and pulse duration. This control sends an output pulse to the high voltage power supply where it is voltage amplified. The high voltage power supply consists of a number of power supplies (from 1 to 2 kV) cascaded to give the desired output voltage. The power supply input is a rechargeable auxiliary battery of about 100 Vdc to buffer the high power (20 kW) in each aurora pulse. The electron gun requires a filament current control and focusing and grid screen control unit. The electron gun control also requires timing signals and pulse characteristic signals from the high voltage power supply. The electron gun may be a single gun for the echo mode and several guns operated in parallel for the artificial aurora mode. The electron gun is mounted on a gimbaled platform to orient the beam to various pitch angles with the magnetic field lines.

An electron echo will be received at the Shuttle position for some mirror points. A boom-mounted electron detection package consisting of an electrostatic analyzer for energy spectra analysis and a solid-state detector for echo timing will be used. Three or more electrostatic analyzers, each covering a narrow energy range, are required. The outputs of the analyzers are channel electron multipliers which are counted in high speed scalers. The scalers are cleared in short time intervals ($\approx$ 1 msec) to give an energy and time signature of the echo. A wide angle solid-state detector is used for more accurate echo timing. The detector and preamplifier integrate the detected electrons over the echo pulse. A pulse from the electron accelerator is used as a start pulse, and the time and height of the echo pulse are digitized, displayed, and recorded.

The proposed plasma gun experiments are more varied than those for the electron accelerators. Experiments call for injecting H^+, He^+, He^{++}, Ba^+, Li^+, Cs^+, and Na^+ in either a plasmoid or in a way to fill a field line with plasma. It

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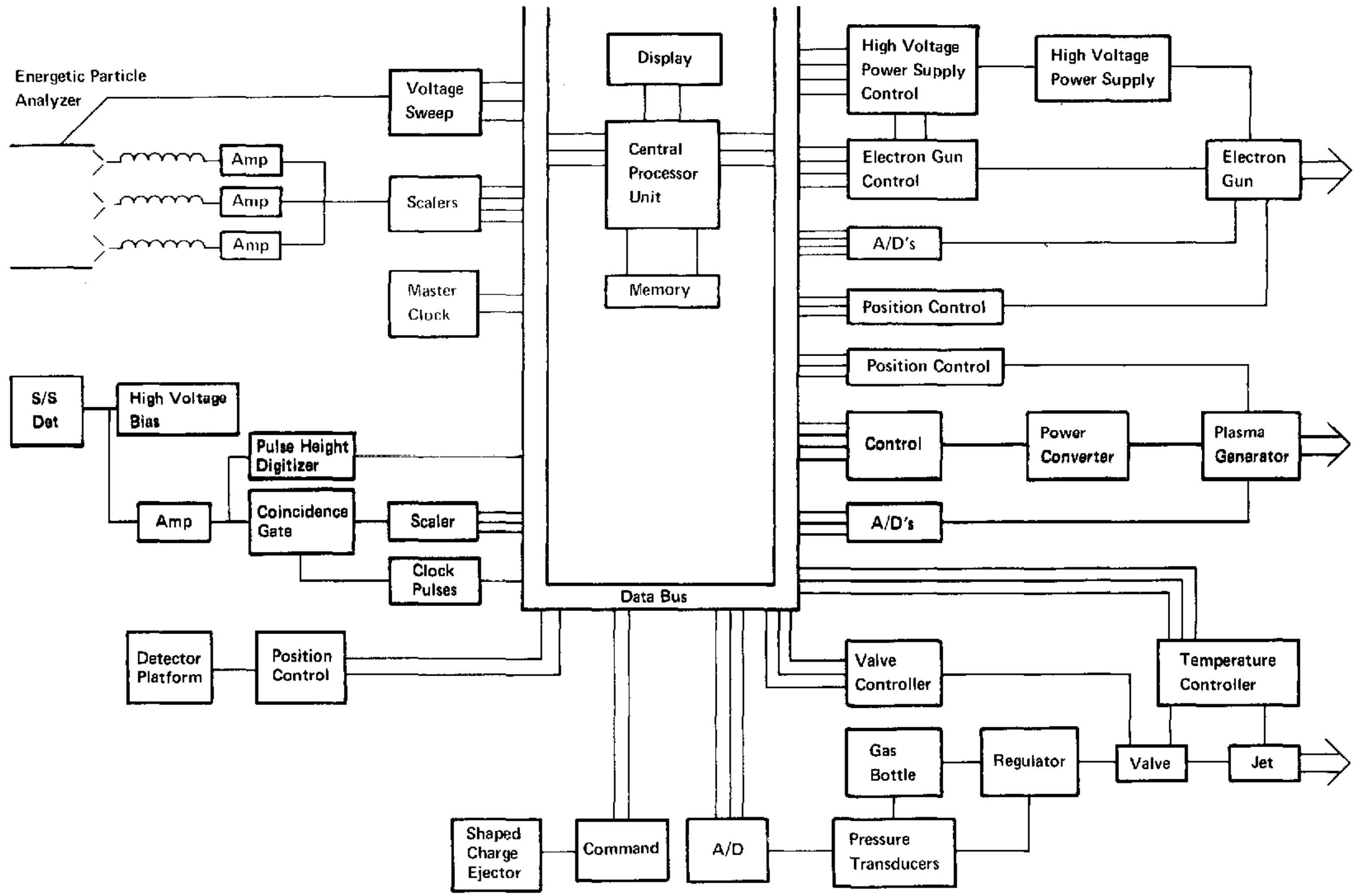

Figure 3.3-2 Auroral and Magnetospheric Observatory - Accelerator and Gas Release

has not been determined whether a single plasma generator with limited experiment objectives or more than one generator will be carried. A generalized block diagram for a single plasma generator is shown in Figure 3.3-2. The plasma generator is on a gimbaled platform. A plasma control unit is used to generate pulse wave forms that control plasma intensity and duration, and the acceleration voltage. A power converter operates from these control pulses to generate the desired plasma. Feedback control is through A/D conversion of analog outputs in the plasma gun, then through computer processing to the plasma control unit.

Another technique for releasing ionized vapor is to eject canisters which use a shaped charge to release vaporized metal ions. This technique has been successful for release of Ba^+ ions. Commands are sent to a canister ejector, which has self-contained firing circuits.

Another technique is the release of a cold plasma. The gas is jetted from nozzles from gas storage bottles. The gas release requires valve control, pressure control, and for some gases, temperature control to prevent condensation in the pressure regulator and nozzle.

The NIM-CAMAC implementation of the accelerators and gas release is shown in Figure 3.3-3. The electrostatic analyzer sweep voltages are generated by a CAMAC D/A converter and a NIM programmable high voltage power supply. The channeltron output is fed into NIM preamplifier, amplifier, discriminators and then into CAMAC scalers. A CAMAC real-time clock gates the scalers to give the time versus energy spectra of the electron echo.

The solid-state detector bias supply is NIM, and a CAMAC D/A converter allows control of the bias voltage through the keyboard. The pulse-height digitizer and timer modules are standard CAMAC modules. The detector platform uses CAMAC-controlled stepper motors.

The electron and plasma accelerators are conceptual at this time. Most of their electronics are not suitable for either NIM or CAMAC. Output registers for commands, 16-input A/D converters for voltage and current monitoring, and D/A controllers for voltage adjustments are available for computer control of the accelerators. A real-time clock can program different pulse duration and pulse repetition rates. The accelerator platform can be positioned with CAMAC-controlled stepper motors.

The gas release and shaped charge ejectors are CAMAC-controlled through output registers. Twelve-bit (channel) registers with isolated transistors for driving solenoids at a power level of 30 V at 100 mA are available. A 16-input A/D converter allows analog inputs for temperature and pressure control of the gas release experiment.

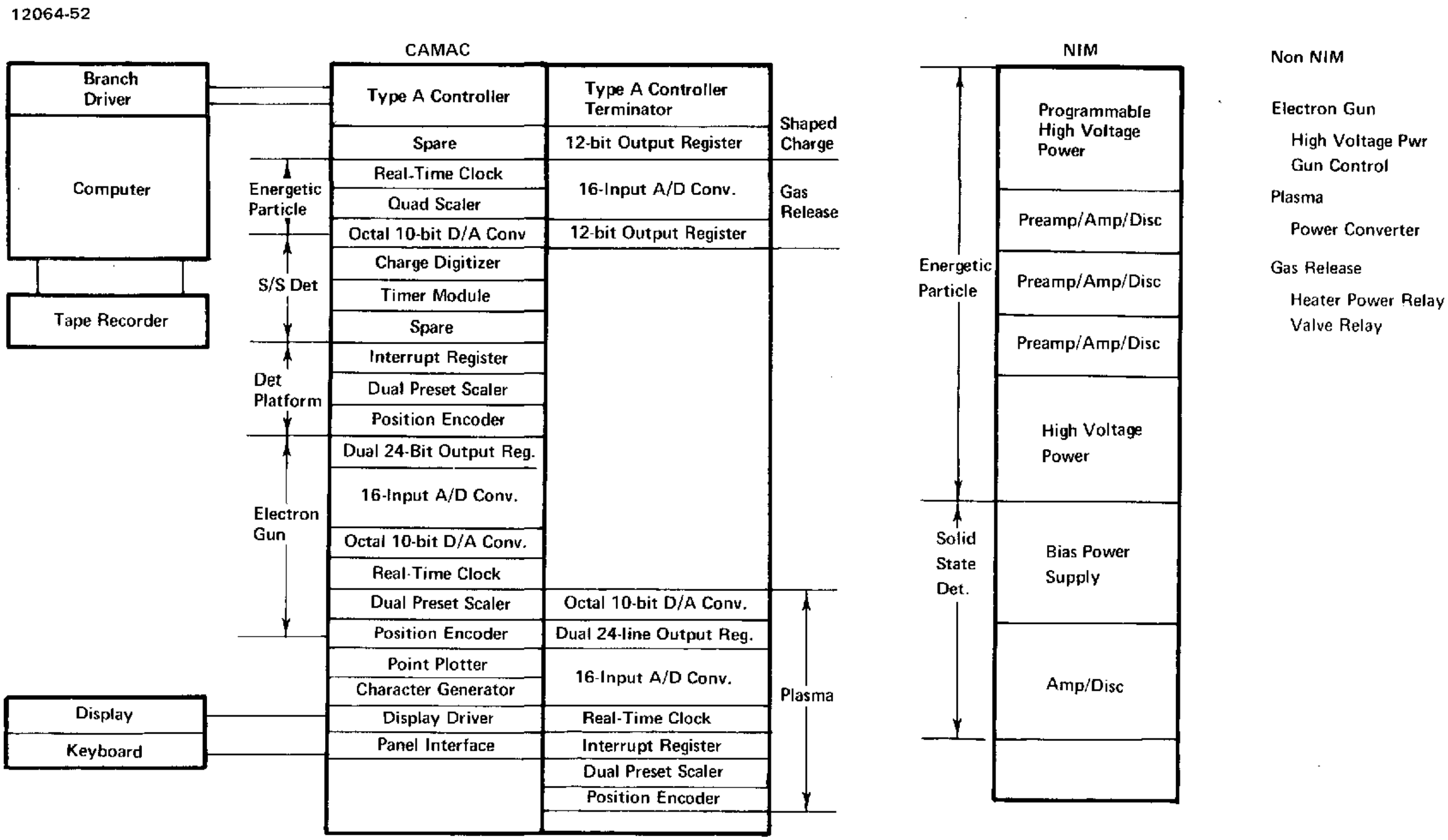

Figure 3.3-3 Auroral and Magnetospheric Observatory – Accelerator and Gas Release

A CAMAC display and keyboard interface provides the payload specialist with control and display of the equipment. A weight, power, and cost summary is shown in Table 3.3-2.

3.3.2 Diagnostic Payload

The diagnostic payload includes passive instruments and active RF transmitters to measure the properties of the magnetosphere. The fluxgate magnetometer, neutral mass spectrometer, ion mass spectrometer, and Langmuir probes have been flown in the past. The functional block diagram for these instruments (Figure 3.3-4) were taken from the literature on the Atmospheric Explorer.*

The electrostatic energy analyzers are conducting spheres placed several meters apart. Both the ac and the dc components are measured. The output is amplified, filtered into narrow bandwidths, and the energy in each bandwidth is integrated and digitized. A range switch electrometer is used for wide dynamic range dc measurements and A/D converters for the ac components.

To extend the frequency range of the magnetic field measurements, search coils are used. The frequency range is filtered into narrow bands, amplified by a gain switchable amplifier, integrated, and A/D converted.

Various experiments involving transmitters and receivers have been proposed for magnetospheric measurements. These operate with long (600 m) dipole antennas. The electronics are not suitable for NIM-CAMAC implementation and were not analyzed in any detail. A characteristic receiver is shown in the functional block diagram. Diplexers are used to switch the antennas from transmit to receive and are controlled by a sequencer. The received signal is controlled by a commandable attenuator, mixed with a commandable VCO, amplified, filtered, and envelope detected. The envelope is A/D converted and stored and displayed.

The NIM-CAMAC implementation of the diagnostic payload is shown in Figure 3.3-5. Most of the CAMAC functions are output registers for commands, A/D converters for digitizing analog signals, and D/A converters for voltage control. The neutral mass spectrometer uses NIM-programmable high voltage power supplies controlled by CAMAC-generated analog voltages. The mass spectrometer has two detectors. Each has a Faraday cup for high partial pressure ($\approx 10^{-11}$ torr partial pressure) gases and an electron multiplier for single ion counting at very low partial pressures. The Faraday cup ion current is measured with a range switching electrometer, which is not available in NIM but could easily be packaged

*Radio Science, Vol 8, No. 4, April 73.

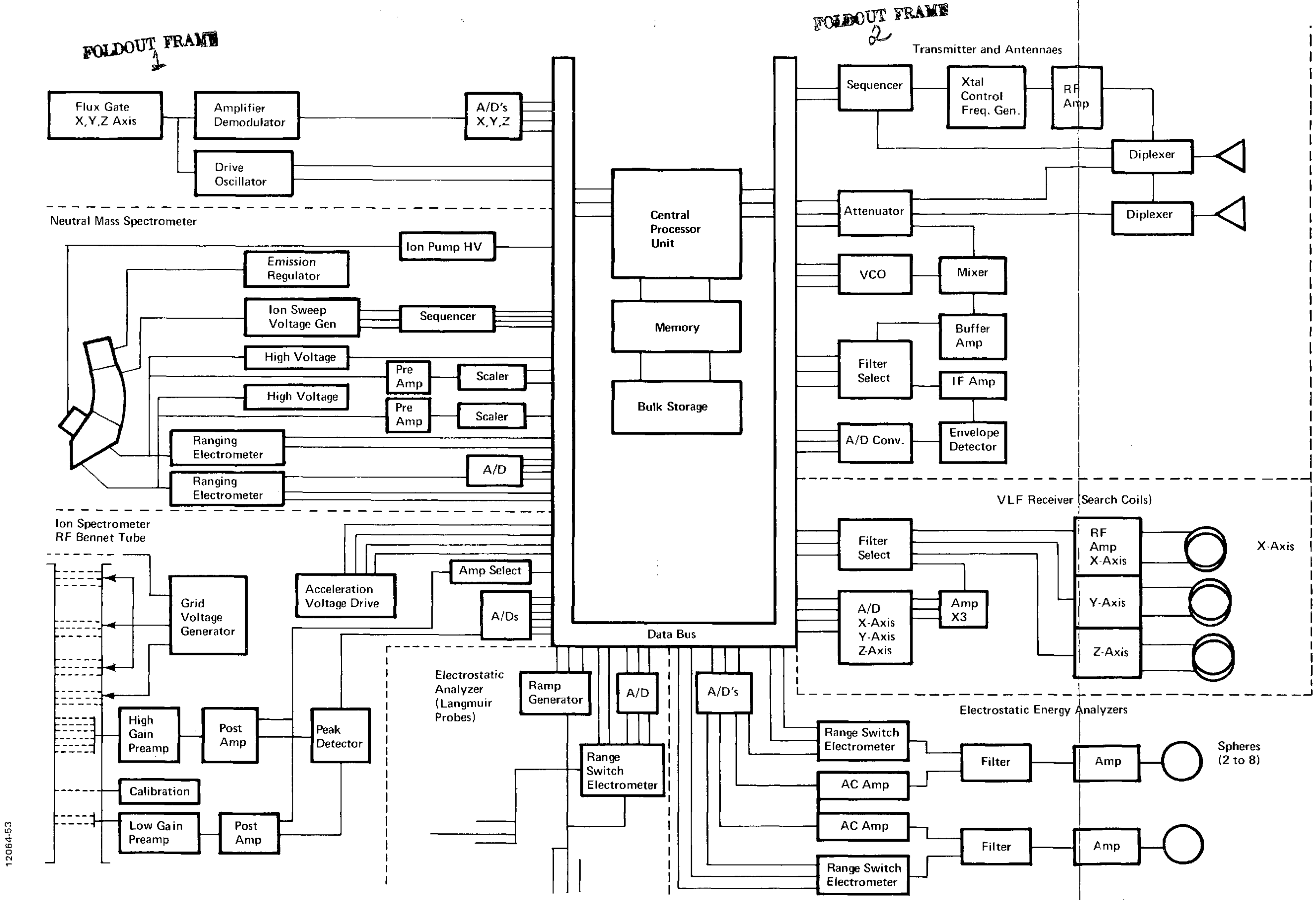

Figure 3.3-4 Auroral and Magnetospheric Observatory Diagnostic Payload

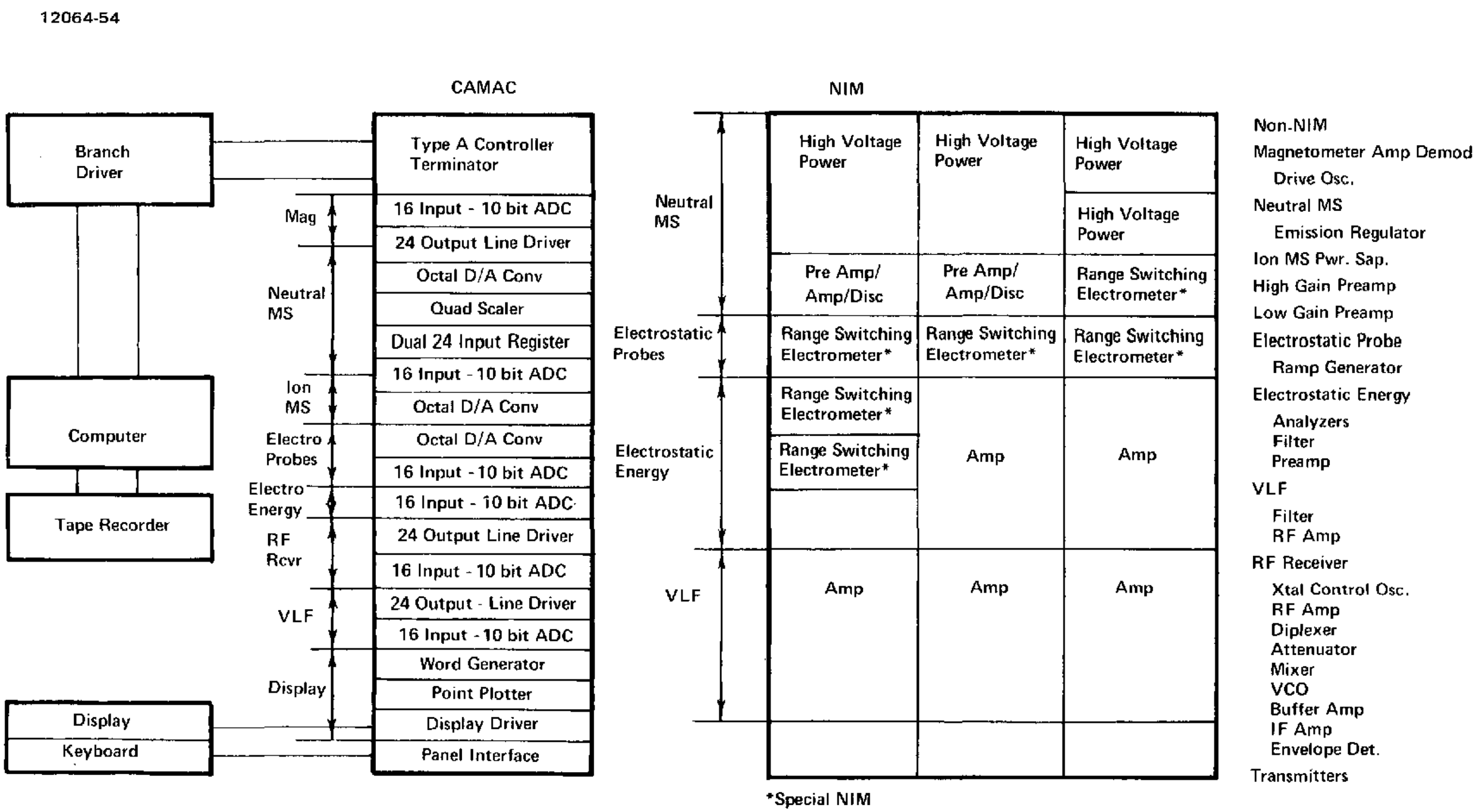

Figure 3.3-5 Auroral and Magnetospheric Observatory Diagnostic Payload Implementation

in a single NIM width module. The electron multiplier is fed into a NIM preamplifier/amplifier/discriminator module and the signal from this module is counted in a CAMAC scaler.

The ion mass spectrometer uses CAMAC D/A converters for grid voltage adjustments and a CAMAC A/D converter. Signal amplifiers and peak detectors are available in NIM (Ortec 439 and 450). However, the units developed for space are better for this application. The electrostatic energy analyzers and the Langmuir probes both use CAMAC A/D converters and special NIM range switching amplifiers. The Langmuir probes also use CAMAC D/A converters for generating probe bias voltages.

The RF receivers use CAMAC output registers for commanding the attenuators, filters, VCO, and CAMAC A/D converters. Low frequency (≈ 100 Hz to 1.6 MHz) amplifiers are available in NIM for the VLF receiver.

CAMAC drive displays and keyboard are used. The high data rates from the RF receivers and the AC Electrostatic Energy Analyzers place a large demand on data processing on the computer. This demand requires further analysis to determine whether a DEC PDP-11 capacity computer is capable of handling the high data rate. Table 3.3-3 summarizes the weight, power, and cost of the Aurora and Magnetospheric Observatory Diagnostic Payload.

Table 3.3-2

Aurora and Magnetosphere Observatory Accelerator and Gas Release NIM-CAMAC Summary

Module	Weight (kg)	Power (W)	Cost ($)
CAMAC Module			
Branch Driver BD-011[a]	11.4	60	4,800
Crate Power Supply (2) MC100[a]	45.4	260	3,090
Type A Controller (2) CC101[a]	2.8	24	2,700
Terminator BT-01[b]	0.1	1.8	295
Real-Time Clock (3) RC014[a]	2.4	13	1,785
Quad Scaler S003[a]	0.9	7.8	495
Charge Digitizer QD410[a]	1.8	13.56	1,600
Timer Module 3655[b]	0.5	5.4	825
Interrupt Register (2) IR026[a]	1.6	5.8	790
Dual Preset Scaler (3) PS016[a]	2.7	12.42	2,280
Position Encoder (3) PE019[a]	2.4	19.9	2,370
Dual 24-Line Output Register (2) R0224[a]	1.8	12.0	1,150
16-Input A/D Converter (3) 5301[c]	3.0	24.0	4,500
Octal 10-bit Converter (3) 3110[b]	1.5	21.0	1,935
Point Plotter PP012[a]	0.9	6.78	985
Character Generator CG018[a]	0.9	8.7	985
Display Driver DD015[a]	0.9	2.22	510
Panel Interface (Estimate)[a]	1.4	8.0	1,500
NIM Module			
NIM Bin 402[a]	14	60	830
High Voltage Power (3) 456[a]	10.8	150	1,530
Amplifier (3) 485[a]	2.7	6.36	780
Amplifier/Disc 486[a]	1.35	6.8	510

( ) Numbers in parentheses refer to number of modules.

(a) Manufactured by EG&G/Ortec.

(b) Manufactured by Kinetic Systems.

(c) Manufactured by Bi Ra Systems.

Table 3.3-3

Aurora and Magnetospheric Observatory Diagnostic Payload

Module	Weight (kg)	Power (W)	Cost ($)
CAMAC Module			
Branch Driver BD-011[a]	11.4	60	4,800
Type A Controller CC101[a]	1.4	12	1,350
Terminator BT-01[b]	0.1	1.8	295
16-Input-10-bit AD Converter (6) 5301[c]	6	48	9,000
Octal D/A Conv. (3) 3110[b]	1.5	21	1,935
Dual 24-bit Input Reg. RI224[a]	0.9	6	525
Dual 24-bit Output Reg. (3) RO224[a]	2.7	18	1,725
Quad Scaler S003	0.9	7.8	495
Character Generator CGO18[a]	0.9	8.7	985
Point Plotter PP012[a]	0.9	6.8	985
Display Driver DD015[a]	0.9	2.2	510
Panel Interface (Estimated)[a]	1.4	8	1,500
NIM Module			
NIM Bin (3) 402[a]	42	180	2,490
High Voltage Power (2) 456[a]	7.2	100	1,020
High Voltage Power (2) 459[a]	1.8	9	850
Amplifier (5) 450[a]	12.5	62	5,725
Amplifier (2) 485[a]	1.8	6.2	520

( ) Numbers in parentheses refer to number of modules.

(a) Manufactured by EG&G/Ortec.

(b) Manufactured by Kinetic Systems.

(c) Manufactured by Bi Ra Systems.

3.4 SHUTTLE SORTIE COSMIC RAY LABORATORY

The Shuttle Sortie Cosmic Ray Laboratory is conceived of as a standardized environment in which experiments can be installed and performed with a minimum of time and effort. The laboratory is a pallet configuration. The electronics are housed in a pressurized container, and the experimental apparatus is housed in the same container with the electronics or on an unpressurized mount on the pallet. The laboratory would operate attached to the Shuttle pallet for a 7-30 day mission. The mode of usage would be multiple experiments in each flight with reuse of the basic laboratory throughout the 1980's. The laboratory-Shuttle interface will be essentially unchanged from mission-to-mission. Primary means of experiment control would be through a data link to an experiment console in the Shuttle crew compartment and/or the ground as the experiment requirements dictate.

The definition of the electronics for the feasibility analysis of using NIM-CAMAC equipment is based on the NASA-JSC balloon experiment. This experiment is being designed as a candidate Shuttle payload and represents the type of requirements for cosmic ray experiment electronics.

3.4.1 Instrument Description

The instrument is a magnetic particle spectrometer consisting of a charge identification module, particle trajectory mapping modules, a super-conducting magnet, and a calorimeter. Figure 3.4-1 is a functional block diagram of the experiment.

The charge identification module uses both a Cerenkov gas detector and a plastic scintillor. The Cerenkov detector and the scintillator are each viewed with four photomultiplier tubes. The anodes of the Cerenkov tubes and the anodes of the scintillator tubes are separately summed and sent to a square root pulse-height discriminator (PHD). The last dynodes of the Cerenkov tubes and the last dynodes of the scintillator tubes are summed, discriminated with a commandable threshold, and sent to a fast coincidence gate. Each discriminator has three commandable threshold levels. The fast coincidence gate has 11 command steps. The command steps and discriminator levels are shown in Table 3.4-1. Since the coincidence gate represents a single point failure, redundant gates are used.

The particle trajectory mapping module consists of four multiwire proportional counters. The outputs of the wires are stored on a delay line and then read out when the proper coincidence criteria are met. Time-to-digital converters (TDC) measure the time from a start pulse to the time required for a pulse to travel down the delay line. The delay line is connected to the multiwire proportional counter so that the time delay corresponds to the wire position where the

FOLDOUT FRAME 1

FOLDOUT FRAME 2

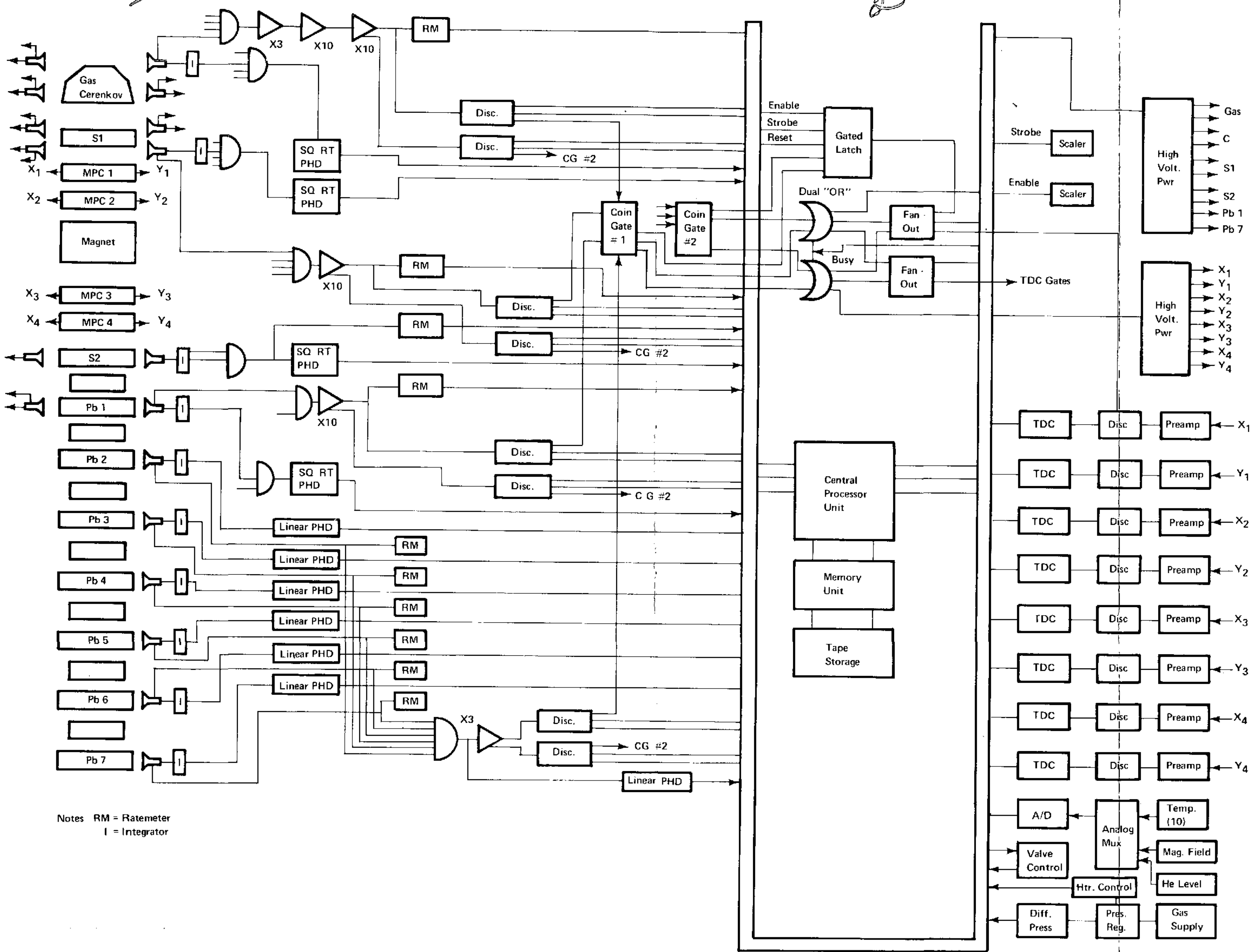

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Figure 3.4-1 Shuttle Cosmic Ray Laboratory

Table 3.4-1

Commands

Discriminator	Levels	
Cerenkov Detector,	(1)	OFF
Scintillator S1, and	(2)	1
Scintillator PB1	(3)	4
Sum of Scintillator PB2-PB7	(1)	OFF
	(2)	1 = 40 mV
	(3)	10 = 400 mV

Coincidence Units

Command Step	Input Controls A	B	C	D	Level Control
1					Quad
2	OFF				Triples
3		OFF			↕
4			OFF		
5				OFF	Triples
6	OFF	OFF			Doubles
7	OFF		OFF		↕
8	OFF			OFF	
9		OFF	OFF		
10		OFF		OFF	
11			OFF	OFF	Doubles

charged particle traversed the counter. The particle trajectory is measured on entry and on the exit from the magnetic field.

The calorimeter is a lead-scintillator sandwich. The scintillator photomultiplier dynodes are summed, discriminated with a commandable threshold, and the output signal sent to the fast coincidence gate. Each anode is connected to a linear pulse-height digitizer. The output of all pulse-height digitizers are telemetered or recorded.

The housekeeping measurements of temperature (10), magnetic field strength, and helium level are analog multiplexed into the data stream. The remaining electronics are for gas control for the multiwire proportional counters.

3.4.2 NIM-CAMAC Implementation

Since NIM and CAMAC modules have been developed for high energy physics experiments, over 90% of the cosmic ray laboratory electronics can be implemented with standard NIM and CAMAC units. The implementation is shown in Figure 3.4-2. One CAMAC crate and three NIM bins are required.

The linear pulse-height digitizers for the calorimeter can be handled by one 8-bit, eight-input CAMAC module. Square root pulse-height digitizers for the other scintillators and Cerenkov detector are not available. Instead, 10-bit pulse-height digitizers are used and the computer determines the square root.

Ratemeters are not used with CAMAC; instead, scalers and a real-time clock are used to periodically read out and reset the scalers. Two eight-input scalers satisfy all of the ratemeter requirements.

Addressable discriminators and coincidence gates are not currently available but are anticipated to be available within the next 2 years. If not, CAMAC output registers driving NIM modules could be used. This approach is shown in Figure 3.4-2. A 24-line output register controls one block of four discriminators with three levels per discriminator (12 lines) and four on/off switches in the coincidence gate (leaving eight spare lines). The computer commands the coincidence gate on/off switches to give the command steps shown in Table 3.4-1. The discriminators and coincidence gates are available in NIM and can be modified for remote control. A dual 24-bit output register is used to control the redundant discriminator and coincidence gate. The two times eight spare lines are available for relay control.

Upon receipt of a coincidence, a CAMAC interrupt register is triggered to interrupt data collection while the multiwire proportional counters are read out.

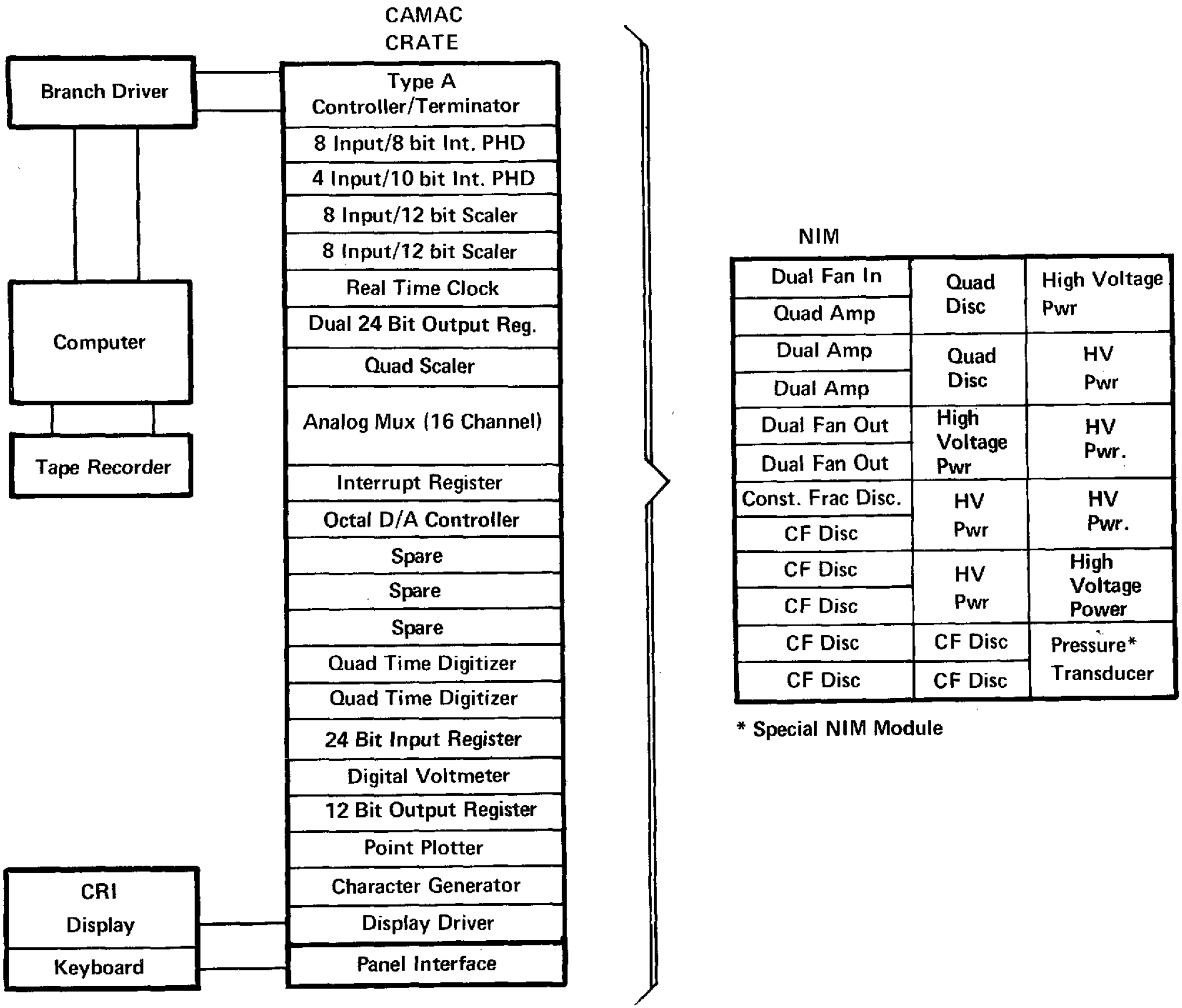

Figure 3.4-2 Shuttle Cosmic Ray Laboratory—NIM-CAMAC

Two CAMAC quad time digitizers provide the readout of the proportional counters. The proportional counter high voltage power supplies are controlled by CAMAC D/A converters. The analog voltage from the D/A converter in turn controls NIM high voltage power supplies.

Two channels of a quad scaler count the number of coincidence events. The "OR" gate is a part of the scaler. The remainder of the electronics are for housekeeping, control of the gas in the proportional counters, and data display. A CAMAC 16-channel analog multiplexer and A/D converter (digital voltmeter) provide temperature, helium level, and magnetic field strength readings. A 24-bit (channel) optically isolated input register provides status flags such as value on or off. The gas supply requires valve control, differential pressure meter, and a heater on restrictors and pressure regulators to compensate for expansion cooling across a pressure drop. A CAMAC 12-bit output register provides the valve control. NIM modules for differential pressure transducers are not available, but the electronics could be packaged in NIM units and use NIM voltages. The heater power is also controlled by on/off commands from the 12-bit output register. The pressure and temperature digitization is through the analog multiplexer.

The display control uses a point plotter, a character generator, and display driver CAMAC modules. A keyboard is used for entering commands, sequence changes, and data display. Bulk data storage is provided by a tape recorder.

Table 3.4-2 shows the weight, power and cost for the modules. The power values shown for the crates and bins are the conversion losses in the power supply based on a 70% conversion efficiency.

Table 3.4-2

NIM-CAMAC Weight, Power, and Cost Summary

Module	Weight (kg)	Power (W)	Cost ($)
CAMAC			
Crate-Power Supply MC100[a]	11.4	13.0	1,545
8-input/8-bit Int. PHD QD808[a]	0.9	12.3	1,450
4-input/10-bit Int. PHD QD410[a]	1.8	13.56	1,600
8-input/12-bit Scaler (2) S812[a]	1.8	16.4	1,090
4-input/16-bit Scaler S003[a]	0.9	7.8	495
Real-Time Clock RC014[a]	0.8	4.32	595
Dual 24-Bit Output Register RO224[a]	0.9	6.0	575
Interrupt Register IR026[a]	0.8	2.88	395

Table 3.4-2 (Cont.)

Module	Weight (kg)	Power (W)	Cost ($)
Octal D/A Controller 3110[b]	0.5	7.0	645
Quad Time Digitizer (2) TD104[a]	1.8	28.0	2,100
Analog Mux (16 Channel) 5301[d]	1.0	8	1,500
Digital Voltmeter DV013[a]	0.9	4.3	705
12-bit Output Register 3082[b]	0.5	3.9	425
24-bit Input Register 3471[b]	0.5	2.7	565
Point Plotter PP012[a]	0.9	6.78	985
Character Generator CG018[a]	0.9	8.7	985
Display Driver DD015[a]	0.9	2.22	510
Type A Controller CC101[a]	1.4	12	1,350
Terminator BT-01[b]	0.1	1.8	275
Branch Driver	11.4	60.0	4,800
NIM			
NIM Bin (2) 401B[a]	28	100	1,630
Blank Bin for HV Pwr 401A[a]	5.3	0	150
Dual Fan In 127[c]	0.4	5.0	425
Quad Amp 334[c]	0.4	3.84	525
Dual Amp (2) 234[c]	0.8	16.8	910
Dual Fan Out (2) 128[c]	0.8	6.3	850
Const. Frac. Disc. (8)473[a]	8.8	41.0	5,200
Quad Disc. (2) 321B[c]	1.6	17.6	1,450
High Voltage Pwr (8) 456[a]	28.8	400.0	4,080

( ) Number of modules required. Weight, power, and cost are for the total number of modules.

[a] Manufactured by EG&G.

[b] Manufactured by Kinetic Systems.

[c] Manufactured by LeCroy Research Systems.

[d] Manufactured by Bi Ra Systems.

3.5 ORBITAL 13-BAND MULTISPECTRAL SCANNER

This section describes the applicability of NIM-CAMAC modules to the NASA Skylab S-192 orbital 13-band multispectral scanner (MSS). The MSS instrument was part of the Skylab Earth Resources Experiment Package (EREP).

3.5.1 Instrument Description

The MSS was a line scan multispectral scanning radiometer that optically scanned successive contiguous lines across the Skylab flight path. Through this scanning action, the MSS recorded, simultaneously on 13 spectral bands, energy reflected and emitted by earth features. The resulting 13-band image data can be processed to identify and infer properties of terrain features overflown.

The S-192 MSS was mounted in the Skylab multiple docking adapter (MDA). It consisted of two MSS unique assemblies, the scanner assembly and the digital electronics assembly, and two EREP support assemblies, the EREP control and display panel, and an AR-728 tape recorder. These basic assemblies were interconnected as shown in Figure 3.5-1. The scanner assembly was composed of two subassemblies, the internal scanner and external scanner. The external scanner subassembly consisted of a telescope, an electromechanical optical scan mechanism, a protective door and drive, and housekeeping, drive, and sensing electronics which must be closely located to the other components. Principal electronics of the MSS were located in the internal electronics and digital electronics assemblies.

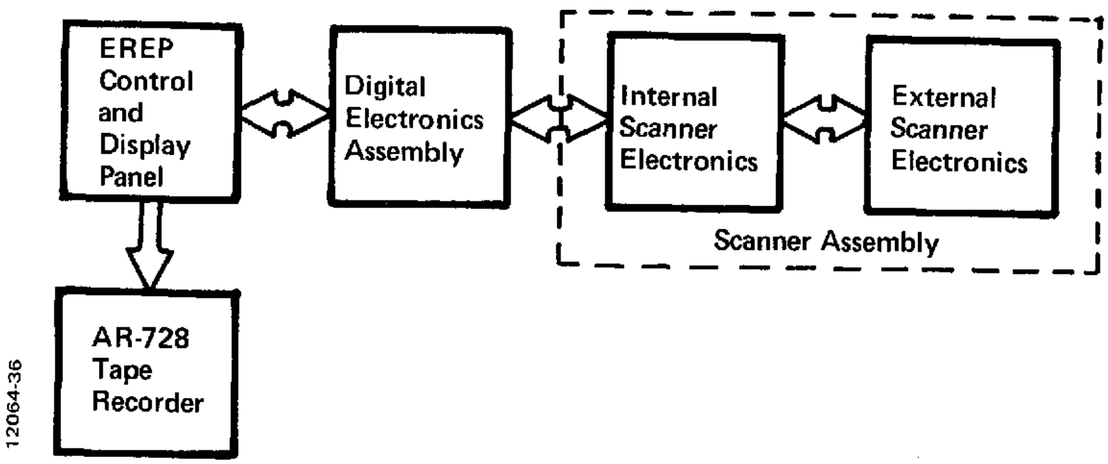

Figure 3.5-1 S-192 Functional Block Diagram

Figure 3.5-2 shows a detailed block diagram of the MSS electronics. Basic timing for the MSS is derived from the clock and timing circuit, which generates a reference frequency for the scan motor drive and data clocks for sampling, digitizing and recording both image and housekeeping data. Timing for frame synchronization and calibration source location is generated by a scan shaft position encoder in the external scanner electronics.

The scan motor rotates the scanning mirror at a rate closely controlled to the reference frequency producing contiguous scan lines across the flight path. The telescope focuses energy from the terrain scanned on the 13 detectors in the internal scanner electronics.

Signals from the detectors are amplified in 13 preamplifiers and 14 video processing amplifiers and then digitized to eight bits in 14 A/D converters. The signal from band 13 preamplifiers drives two video processing amplifiers and A/D converters, which are sampled at different rates to produce two different picture element (pixel) resolutions. When the detectors are viewing calibration sources during each scan line, output words from each A/D converter are compared with reference levels to derive video processing amplifier gain and offset signals. These gain and offset signals adjust the video amplifiers to produce calibrated data outputs.

Terrain signal data are collected during 120° rotation of the scanning mirror. To reduce the recording data rate, a buffer stores data over the 120° scan period and outputs a line of data over the 360° scan mirror rotation period. This data buffer is also used to multiplex the 14-channel data onto 22 tracks of the tape recorder. Output from the data buffer is via 22 output shift registers and sync word generators, which add a line sync bit pattern at the beginning of each scan line. Twenty-four line drivers are used to drive the cables interconnecting the digital electronics assembly and the Control and Display (C&D) panel as shown in Figure 3.5-2. Twenty-two of these outputs carry image data, one carries housekeeping data, and one carries a data clock required by the Miller encoders in the C&D panel. Twenty-three Miller encoders drive tape recorder tracks as summarized in Table 3.5-1. The housekeeping data track contains data from the sensors listed in Table 3.5-2 each of which is sampled once per scan line. Table 3.5-3 summarizes the scan rate, sampling and digitizing rates, and data buffer requirements for both the image and housekeeping data.

Operator control of the MSS is by way of the C&D panel. The operator monitors the status and performance of the instrument on indicator lamps and monitors meter readings which can be switched to observe important housekeeping parameters. Figure 3.5-3 shows typical circuits for the C&D panel electronics. In operation, the instrument status is observed on the C&D panel, the tape recorder is started,

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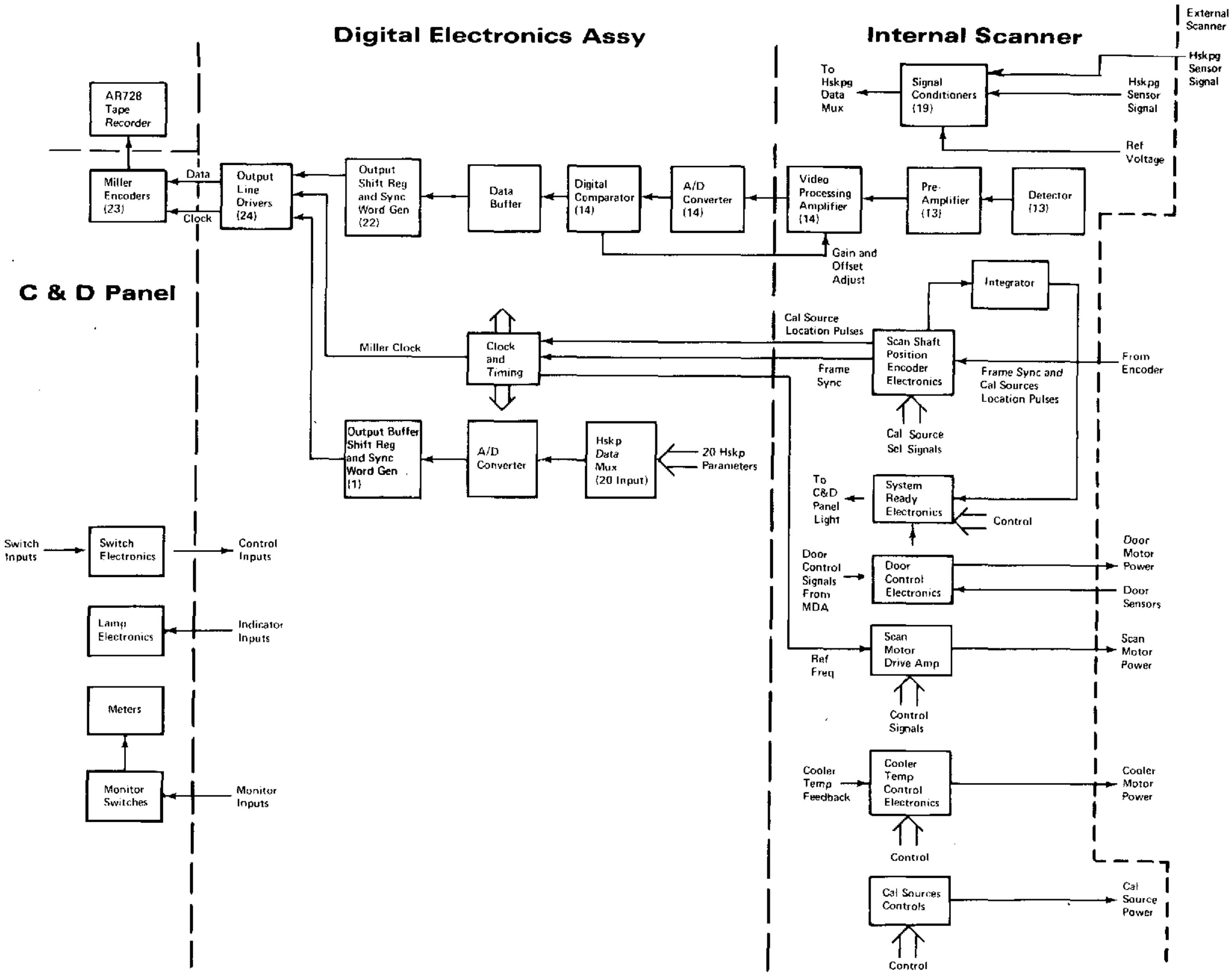


Figure 3.5-2 S-192 13-Band Multispectral Scanner Electronics

Table 3.5-1

S-192 Band and Tape Recorder Track Assignments

Band No.	Track No.	Description	Range	Samples/ Scan
3	3 4	Blue-Green	0.52 to 0.56μ	2,480
4	5 6	Green-Yellow	0.56 to 0.61μ	2,480
5	7 8	Orange-Red	0.62 to 0.67μ	2,480
6	9 10	Red	0.68 to 0.76μ	2,480
7	11 12	Infrared	0.78 to 0.88μ	2,480
11	13 16	Infrared	1.55 to 1.75μ	2,480
12	17 18	Infrared	2.10 to 2.35μ	2,480
13-2	19 20	Thermal Infrared	10.2 to 12.5μ	2,480
8	23	Infrared	0.98 to 1.03μ	1,240
9	24	Infrared	1.09 to 1.19μ	1,240
10	21	Infrared	1.20 to 1.30μ	1,240
1	26	Violet	0.41 to 0.46μ	1,240
2	22	Violet-Blue	0.46 to 0.51μ	1,240
13-1	25	Thermal Infrared	10.2 to 12.5μ	1,240
---	1 27	Housekeeping	20 analogs	1

Table 3.5-2

S-192 Housekeeping Parameters

Hot Blackbody Temp Sensor "1A"

Cold Blackbody Temp Sensor "2A"

Lamp 1 Current Monitor

Redundant Blackbody Temp Sensor "3A"

Lamp 2 Current Monitor

Detector Array Temp Sensor "A"

Primary Mirror Temp Sensor 1

Secondary Mirror Temp Sensor

Primary Mirror Temp Sensor 2

Aspheric Mirror Temp Sensor

Cover Temp Sensor

Scan Motor Temp Sensor

Cooler Motor Temp

Scanner Elect Temp Sensor

Monochromator Temp

Digital Electronic Temp

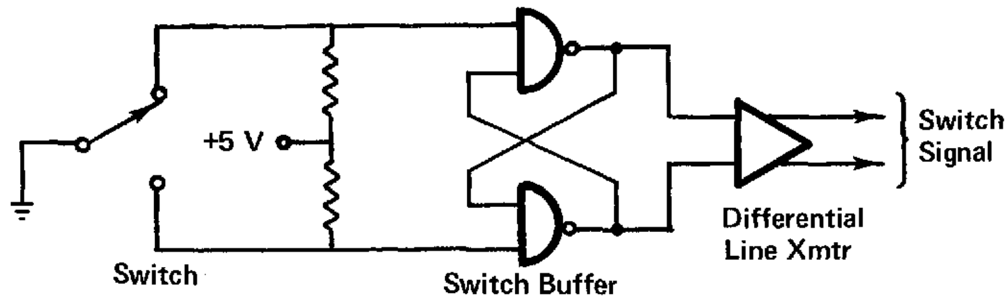
Detector Array Temp Sensor "B"

Hot Blackbody Temp Sensor "1B"

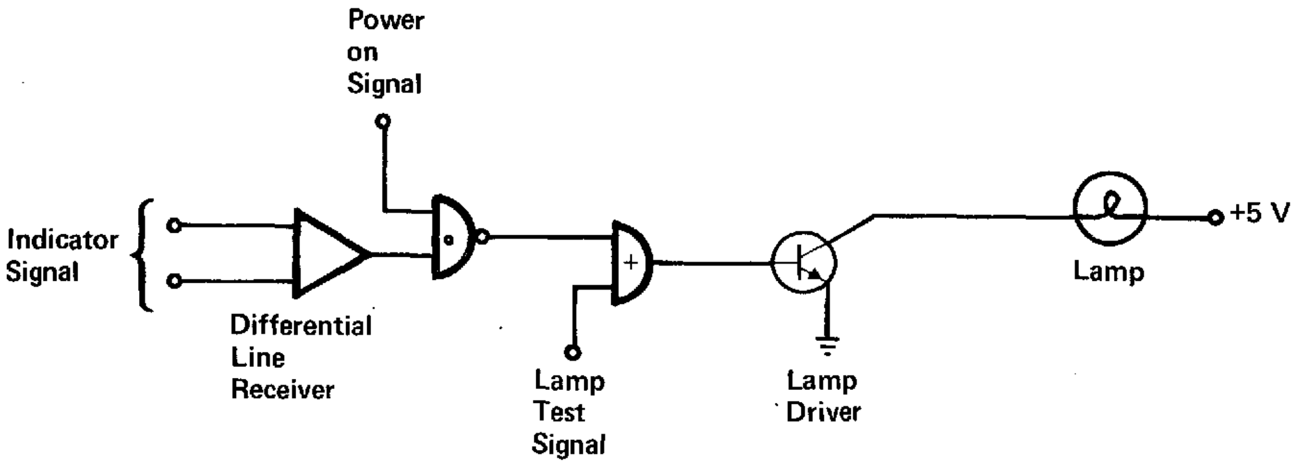
Cold Blackbody Temp Sensor "2B"

Redundant Blackbody Temp Sensor "3B"

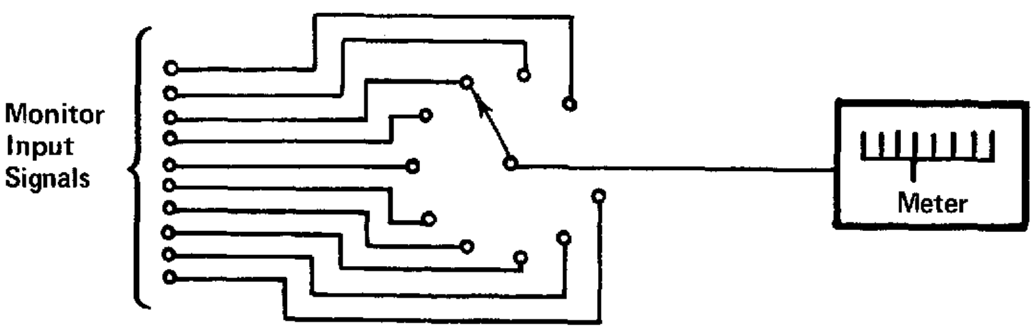
Time (Data Acquisition Delay)



a. Typical Switch Electronics



b. Typical Lamp Electronics



c. Typical Monitor Circuit

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Figure 3.5-3 Typical C&D Panel Circuits

Table 3.5-3

S-192 Data Parameters

1. Electrical Data Bandwidth - 167 kHz

2. Scan Rate - 94.792 mirror rev/sec

3. Data Sampling
   (high resolution - 8 total) - 2,480 samples/scan
   (low resolution - 6 total) - 1,240 samples/scan

4. Sample Rate
   (high resolution) - 1.42 μ sec/sample
   (low resolution) - 2.84 μ sec/sample

5. Housekeeping Data - sampled once per scan line at 2.84 μ sec/data point

6. Data Buffer - Approximately 28K, 8-bit words

the outside instrument door is activated, and the MSS instrument is activated. The instrument is activated in this way by the operator in accordance with a predetermined schedule to collect data over the desired terrain.

In addition to the principal data electronics described above, there are supporting electronics as shown in Figure 3.5-2 including scan shaft position encoder electronics, system ready logic electronics, door control electronics, scan motor drive electronics, detector cooler temperature control electronics, calibration source control electronics, and housekeeping data signal conditioner amplifiers.

3.5.2 NIM-CAMAC Implementation

The NIM-CAMAC implementation of S-192 electronics is shown in block diagram form in Figure 3.5-4. The functional blocks outlined in heavy lines can be implemented in either standard NIM-CAMAC modules or in special design modules using NIM-CAMAC packaging. All other functional blocks would be implemented as they were in the EREP S-192 instrument. The rationale for NIM-CAMAC or non-NIM-CAMAC implementation of each functional block is described in the following paragraphs. Figure 3.5-5 shows a physical configuration of the S-192 NIM-CAMAC electronics.

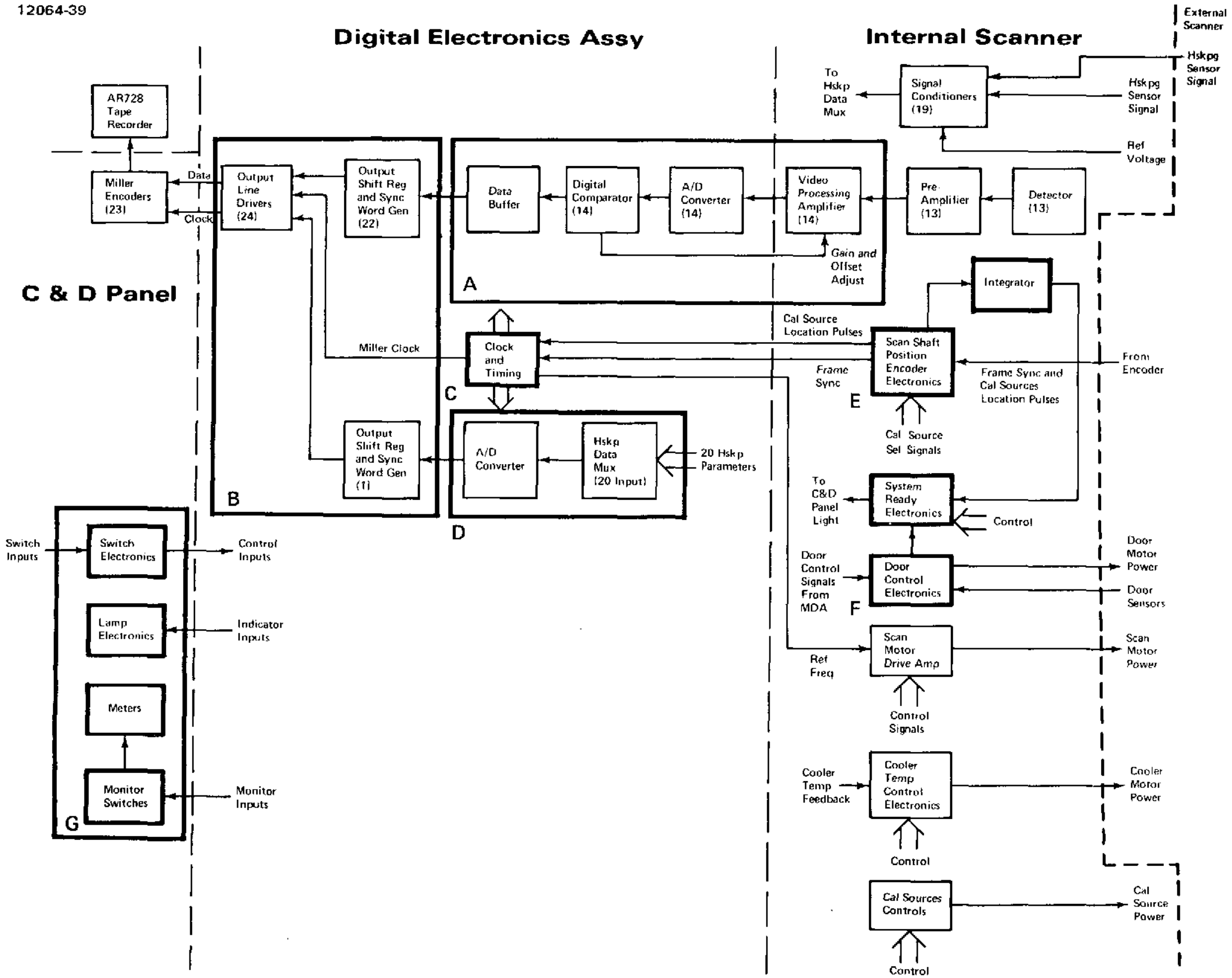

Figure 3.5-4 NIM-CAMAC Implementation of S-192 13-Band Multispectral Scanner Electronics

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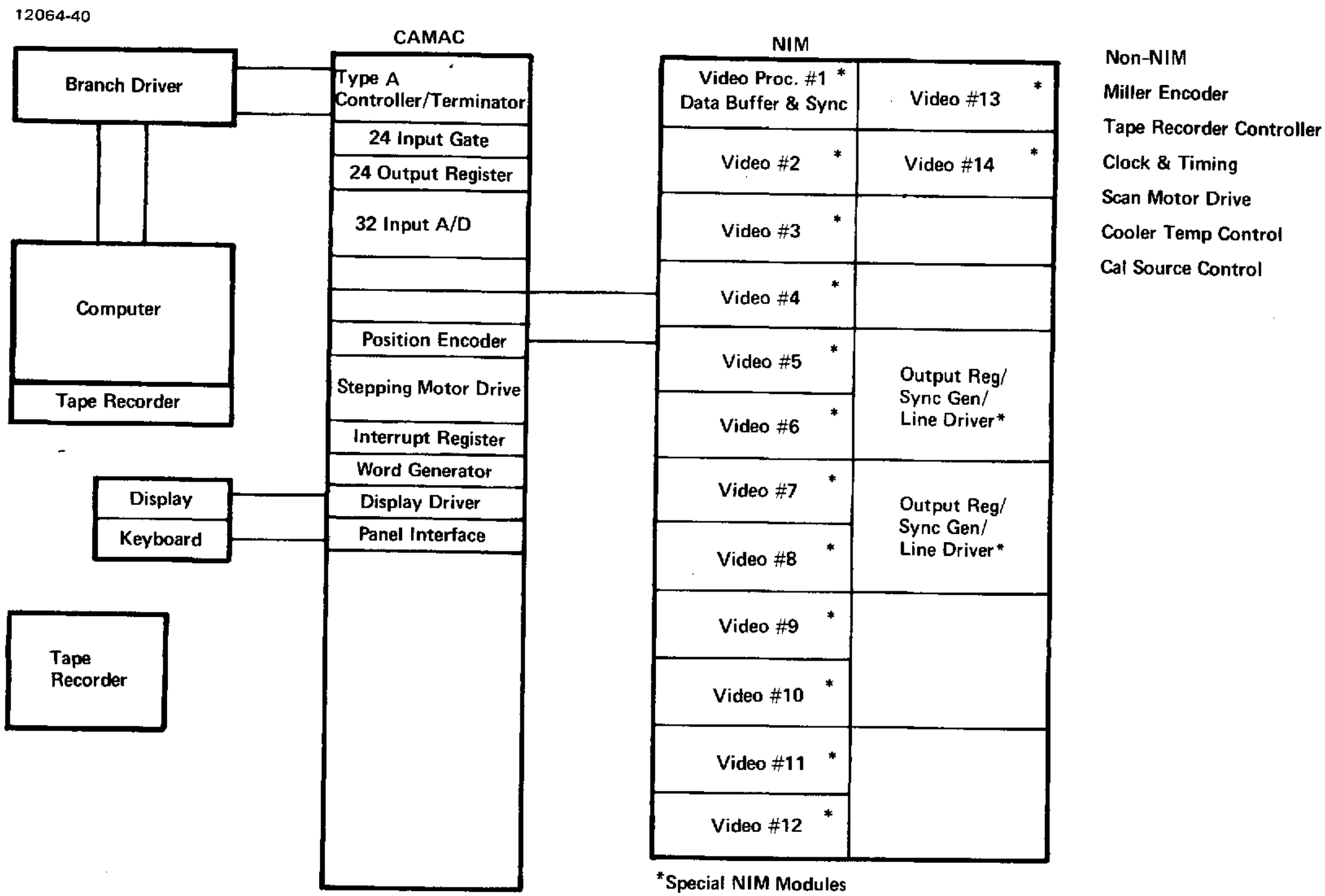

Figure 3.5-5 S-192 13-Band Multispectral Scanner

Consider first the main data path from the detectors to the tape recorder. Preamplifiers for this type of instrument are custom-designed to the specific detectors used and must be located as close to the detectors as possible. Therefore, the preamplifiers would not be NIM-CAMAC. The remainder of the electronics from the video processing amplifiers to the output line drivers could be NIM-CAMAC if suitable modules were available. However, a standard module for the video processing amplifier has not been located, the 1.4-μ sec conversion period required by the A/D converter is too fast for available modules, and the total data rate (over 8 million words per second) is too high for CAMAC implementation. The alternative implementation of the main data path electronics is through the use of NIM-packaged special electronics. Three types of modules are required, which are identified as A, B, and C in Figure 3.5-4. Module A is a NIM-packaged circuit card containing the gain and offset adjusted video processing amplifier, A/D converter, and full scan line buffer. Figure 3.5-6 shows a circuit card containing the Module A electronics but with only an 800-word line buffer. This card could be packaged as a single-width NIM module including the full line 2,480 word buffer. A total of 14 modules would be required. Module B would be a special design NIM module which multiplexes each high resolution channel into two output data tracks, parallel-to-serial converts each data track, adds appropriate sync words, and drives the line to the tape recorder Miller encoders. A total of two double-width NIM packages are required for B modules. The C module is also a special NIM module containing all clock and timing generation for the instrument. A double-width NIM package is required.

Housekeeping data consist of measurement of 20 parameters at various points in the instrument, such as temperatures and voltage levels. The signal conditioner amplifiers must be located at the point of measurement and, therefore, cannot be NIM-CAMAC. The housekeeping data multiplexer and A/D converter can be implemented in standard CAMAC modules. This could be accomplished with two 12-input A/D converters and a 24-output register connected to the housekeeping output buffer in Module B described above. The digitized housekeeping data are also input into the computer for monitor and display on the CRT monitor.

The scan shaft position encoder electronics is a CAMAC module which outputs a count indicating the position of the scan shaft. The encoder output is interfaced to the clock and timing circuit (Module C above) through the 24-output register mentioned above.

The functions of the integrator and system ready electronics are performed by the computer. The necessary input signals interface by way of a CAMAC interrupt register.

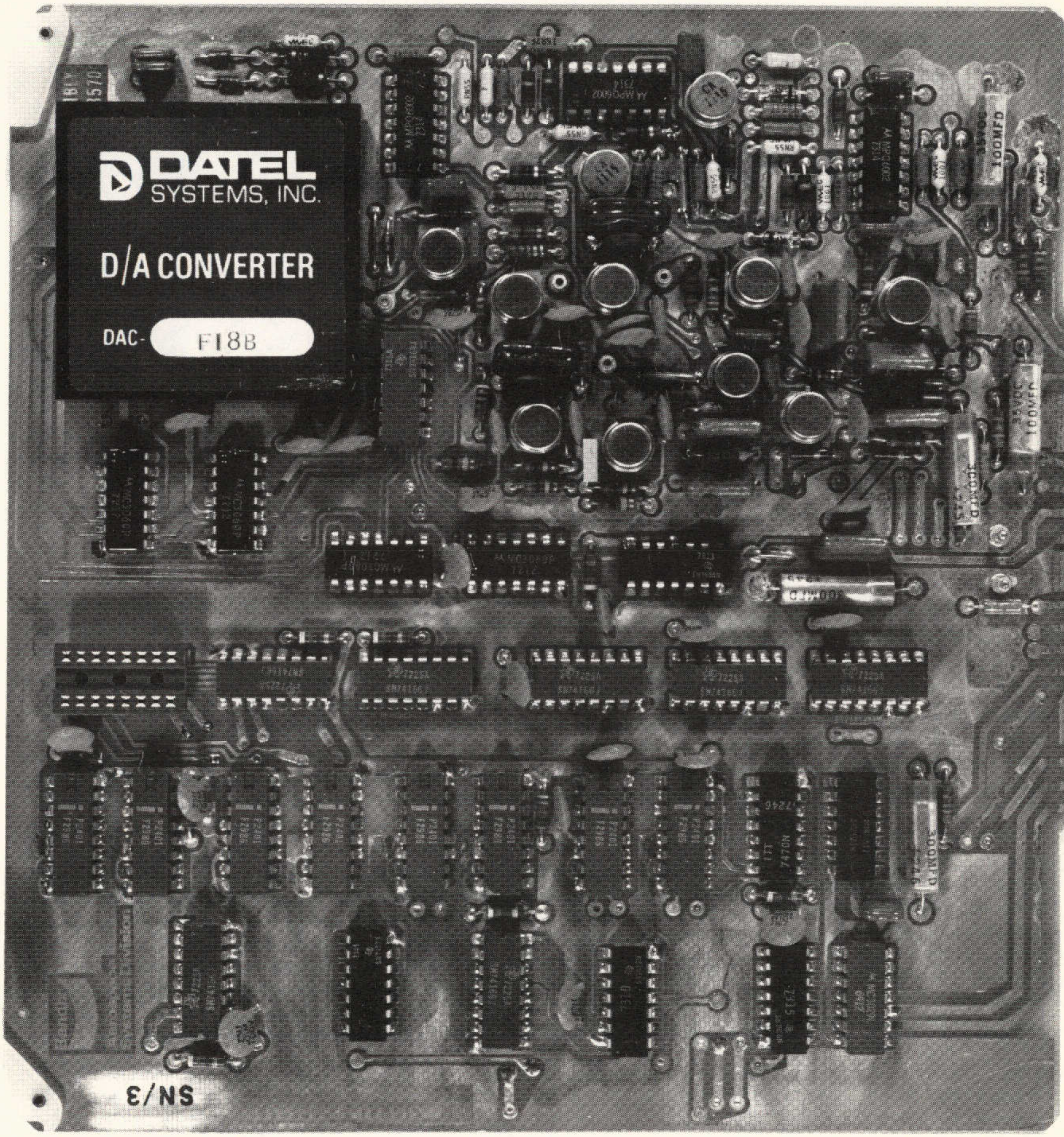

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Figure 3.5-6 MSS Video Processor, Digitizer, and Buffer Card

Door control electronics consist of a CAMAC stepping motor drive unit, with commands from the computer via a CAMAC output register and position data feedback to the computer via a CAMAC input register. These same input and output registers provide the interface between the computer and instrument for command and monitoring purposes.

Command monitor display is provided by the computer keyboard and CRT display as described in the introduction to Section 3.

The scan motor drive amplifier does not lend itself to NIM-CAMAC implementation because the scan mirror/mechanism/motor/amplifier is a high-technology unit requiring a special design to meet the specific scanner requirements. Similarly, the detector cooler temperature control and calibration source control electronics must be specifically designed for the units used so that NIM-CAMAC is not applicable.

The tape recorder is a standard unit, and the Miller encoder electronics are not available as standard units for the tape recorder so that NIM-CAMAC would not be used at this point.

3.5.3 NIM-CAMAC Applicability Summary

As a result of the high data rate and need for some specialized functions such as large high-speed data buffers, standard NIM-CAMAC modules cannot be used for the main data processing electronics. Since these electronics are specialized and to a large extent instrument peculiar, they must be designed and built for such an instrument. As described in Section 3.5.2, these electronics can be designed and implemented in standard NIM-CAMAC packaging which can be supported by standard NIM-CAMAC crates, bins, power supplies, and cabling. In addition, these facilities can be shared with standard NIM-CAMAC modules which can implement supporting functions such as housekeeping data multiplex and A/D conversion, instrument control and monitoring, scan shaft position encoding, system ready logic, and door control electronics. Table 3.5-4 summarizes the weight, power, and cost of the standard modules. Table 3.5-5 is an estimate of the weight and power of the standard and nonstandard modules. Therefore, it is concluded that the large majority of this instrument's electronics could be implemented advantageously in NIM-CAMAC.

Table 3.5-4

Standard NIM-CAMAC Modules Used in S-192

CAMAC Module	Weight (kg)	Power (W)	Cost ($)
Crate Power Supply MC100[a]	22.7	130.0	1,545
Branch Driver BD011[a]	11.4	60.0	4,800
Type A Controller CC101[a]	1.4	12.0	1,350
Branch Terminator BT-01[b]	0.1	1.8	275
Position Encoder PE019[a]	0.8	6.6	790
Stepping Motor Controller 3361[b]	0.5	10.0	725
24-Bit Output Register 3072[b]	0.5	5.7	425
24-Bit Input Gate 3420[b]	0.5	5.7	355
Interrupt Register IR026[a]	0.8	2.9	395
32 Channel Analog Data 5301[c]	1.0	8.0	1,500
Word Generator CG018[a]	0.9	8.7	985
Display Driver DD015[a]	0.9	2.2	510
Panel Interface (Estimate)[a]	1.4	8.0	1,500

[a] Manufactured by EG&G/Ortec

[b] Manufactured by Kinetic Systems

[c] Manufactured by Bi Ra Systems

Table 3.5-5

S-192 Weight and Power Summary

I. NIM-CAMAC Implementation

Component	Weight (kg)	Power (W)
PDP-11/35 Computer	91	150
DEC Tape and Controller	41	870[a]
Terminal-Display and Keyboard	27	130
CAMAC Crate and Electronics	32	200
Branch Driver	11.4	60
NIM Electronics and Bins	46	150
Additional Cables	7	
Scanner Assembly	64 }	180
Spectrometer Assembly	54 }	
Total	373	870

II. Skylab Implementation

Component	Weight (kg)	Power (W)
Scanner Assembly	64 }	
Spectrometer Assembly	54 }	266
Electronics Assembly	36 }	
Control and Display Panel	46 est.	100 est.
Total	200	366

[a] Required only during program change for new instrument or mode modification.

3.5.4 References

The following references to Skylab EREP S-192 were used in preparation of Section 3.5:

1. Skylab Earth Resources Experiments Package (EREP) Systems Handbook, JSC document #MSC-06009.

2. Skylab Program, EREP Investigator's Information Book, JSC document #MSC-07874.

3. Earth Resources Data Format Control Book, JSC document #PHO-TR-543.

3.6 ORBITAL MICROWAVE RADAR SYSTEM

The applicability of NIM-CAMAC modules to the NASA Skylab S-193 radiometer/scatterometer/altimeter is described in this section. This instrument was part of the Skylab Earth Resources Experiment Package (EREP).

3.6.1 Instrument Description

As its name implies, the Orbital Microwave Radar System was actually three instruments sharing common radio frequency (RF) components. The instruments were operated in two basic modes: Rad/Scat mode and altimeter mode. In addition, the antenna had several scanning modes.

The S-193 microwave system was mounted externally on the multiple docking adapter (MDA). It consisted of two unique assemblies, the electronics package and the antenna, and two EREP support assemblies, the EREP Control and Display (C&D) panel and an AR-728 tape recorder. These basic assemblies were interconnected as shown in Figure 3.6-1, the S-193 functional block diagram. Figure 3.6-2 is a detailed block diagram of the S-193 electronics.

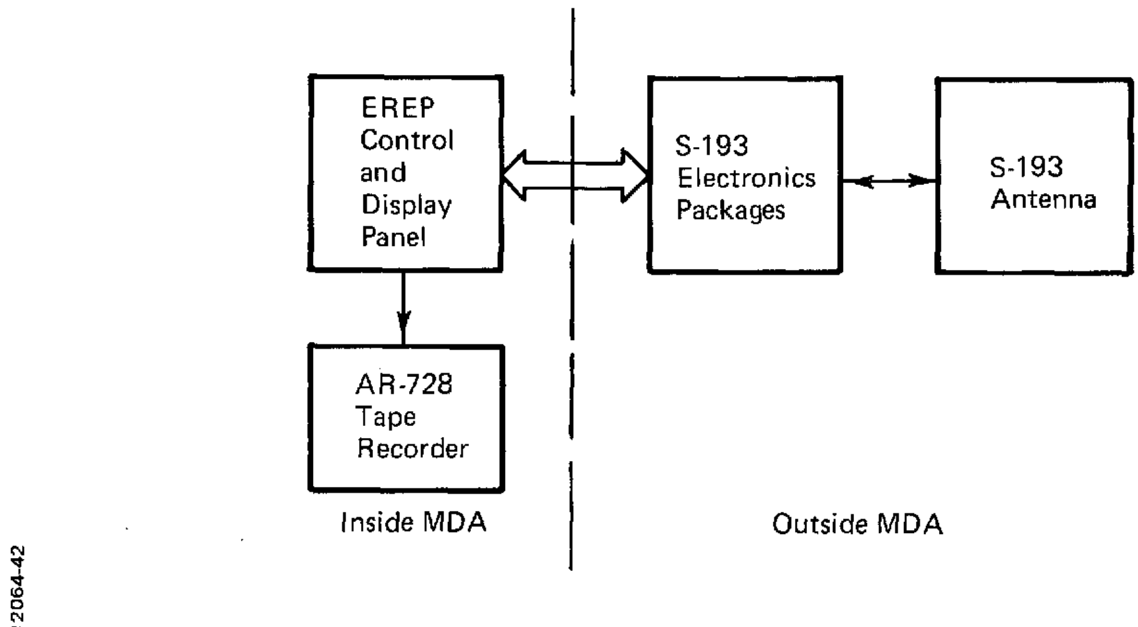

Figure 3.6-1 S-193 Functional Block Diagram

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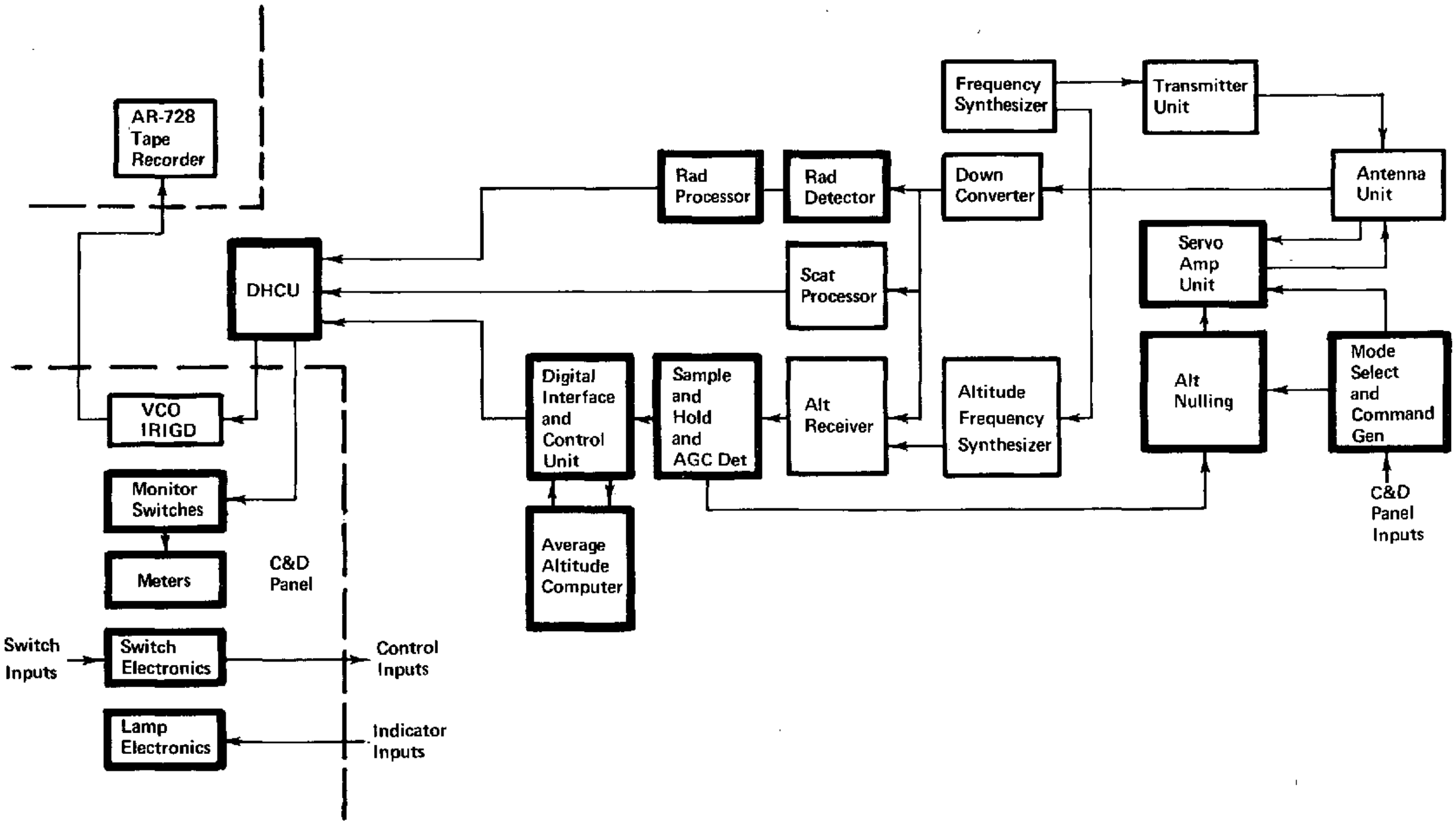

Figure 3.6-2 S-193 Radiometer/Scatterometer/Altimeter Block Diagram

The operation of the sensor in the microwave Rad/Scat mode required nearly simultaneous measurements of the radar differential back-scattering cross section and the passive microwave emissivity of land and sea surfaces. The instrument operated at a single frequency, 13.9 ± 0.1 GHz. The radiometer, scatterometer, and altimeter were capable of operating independently of each other, and also had common components where practicable. The antenna was a mechanically scanning parabolic reflector exhibiting an approximate 1.5° half-power, conical, pencil beam that scanned in several modes. The instantaneous ground coverage was a 6-nautical-mile-diameter circle. During scanning, the beam moved in discrete steps from one surface cell to another in the cross-track noncontiguous (CTNC) and in-track noncontiguous (ITNC) modes, dwelling on each cell a predetermined period of time. During contiguous scan modes, the beam moved continuously, which caused some broadening of the data cell. During any scan mode, the sensor could make a radiometer measurement and a scatterometer measurement in time sequence, or the radiometer or scatterometer could be operated independently. In the Rad/Scat mode, paired values were collected of the differential back-scattering cross section and the total microwave blackbody temperature for each illuminated surface cell in accordance with the space vehicle velocity. The integration times and scan intervals were compatible with the scan mode. The altimeter could not be operated simultaneously with the radiometer, or scatterometer, or both. During Rad/Scat operations, the radar system transmitted a 5.0-msec pulse at a repetition rate of 125 pulses/sec with a minimum power of 8 W. The system had dual polarization and a 23-dB signal-to-noise ratio.

The radiometer operated with the spectral density of thermal noise and a bandwidth that yielded enough independent noise samples to obtain the desired temperature resolution of 1.0°K. The radiometer receiver responded to a temperature range of 50 to 330°K. The radar noise signal was confined to a much smaller bandwidth that was determined by the spread of Doppler frequencies imparted to the transmitted signal by the relative spacecraft motion.

Both instruments operated in a radiometer-like manner. In the case of the radiometer, the noise signal was caused by the thermal emission of a surface cell and was superimposed on the instrument system noise. The noise signal could be recognized as such, and its mean value accurately determined, if it was observed long enough to obtain a sufficient number of independent samples. The result was compared to the measured mean value of another noise source with known temperature. In the case of radar, a sufficient number of independent samples of both signal plus noise and noise had to be taken to obtain a measurement of sufficient accuracy.

The radar scatterometer measured scattering coefficient of the surface at the frequency used. Radar scatter was determined by the roughness and dielectric properties of the target and look angle. Over the ocean, the dielectric properties are essentially the same everywhere, so the scatterometer is a roughness-measuring instrument.

The altimeter was a narrow-pulse radar system designed to provide altitude measurements from the satellite to the sub-satellite point on the ocean surface or on land and provide back-scattered waveform data as a function of angle of incidence through the use of sample-and-hold techniques. The radar system transmitted a 130-, 100-, or 10-nsec pulse at a repetition rate of 250 pulses/sec (single pulse or double pulse) and a peak power of 2 kW. The system had a 20-dB signal-to-noise ratio and operated at a bandwidth of 10 or 100 MHz. The antenna contained a parabolic reflector that exhibitied a 1.5° pencil beam at 13.9 GHz. The received signal passed through a low-noise preamplifier, was down-converted, and square-law detected. The instrument performed in-phase and quadrature detection. The altimeter also had a pulse-compression mode producing a compressed pulse width of 10 nsec. Waveform sampling was performed by eight sample-and-hold gates. The configuration provided a system resolution of 10 nsec (1 meter rms). The altimeter had an automatic nadir-seeker system that provided for nadir pointing to within 0.5°. The nadir search began at a maximum of 4° off the minus Z spacecraft axis and continued in a closing square pattern.

The data formats for the Rad/Scat and altimeter modes are quite different. Table 3.6-1 describes the data format for the Rad/Scat mode and Table 3.6-2 lists the measurements made in this mode. The data format and measurements listed for the altimeter mode are given in Tables 3.6-3 and 3.6-4, respectively.

3.6.2 NIM-CAMAC Implementation

The NIM-CAMAC implementation of S-193 electronics is shown in block diagram form in Figure 3.6-2. The functional blocks outlined in heavy lines can be implemented in either standard NIM-CAMAC modules, in special design modules using NIM-CAMAC packaging, or in other modules of laboratory equipment compatible with NIM-CAMAC. All other functional blocks would be implemented as they were in the EREP S-193 instrument. The rationale for NIM-CAMAC or non-NIM-CAMAC implementation of each functional block is described in the following paragraphs. Figure 3.6-3 shows a physical configuration of the S-193 NIM-CAMAC electronics.

The S-193 functional blocks shown in light borders in Figure 3.6-2 are all RF circuits. The RF units operate in the 500-MHz to 14-GHz region, are not available as standard NIM-CAMAC modules, and are not compatible with standard NIM-CAMAC packaging techniques. There may be modular laboratory equipment which could be used for some functions such as the frequency synthesizer, but

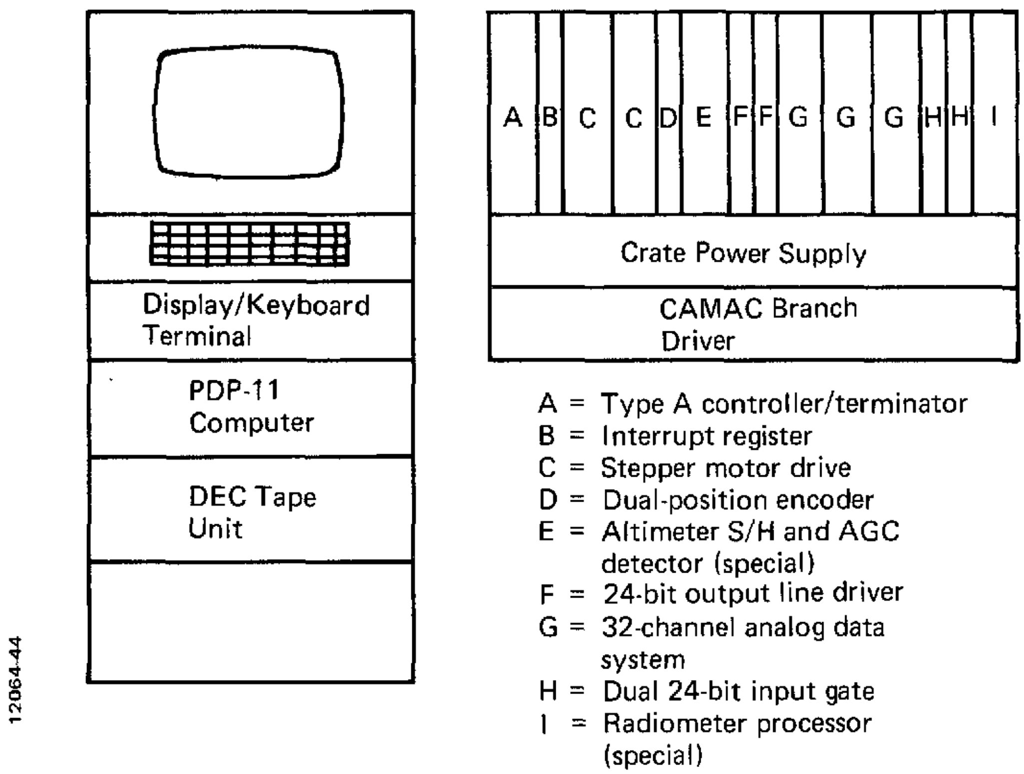

Figure 3.6-3 S-193 CAMAC Electronics

since this was not NIM-CAMAC, it was not further investigated. In addition to the above, components of the RF circuits must be located in close proximity to the antenna and, therefore, in a nonlaboratory hostile environment. For these reasons, none of the RF functions are recommended for NIM-CAMAC implementation.

Table 3.6-1

S-193 Rad/Scat Data Format Characteristics

- The data stream modulates a VCO to produce an output signal on IRIG D. This signal is mixed with IRIG 13 (S194) and IRIG B (S190A) signals and recorded redundantly on tracks 14 and 15 of the EREP tape recorder.
- PCM, split-phase, 5.33 kbps transmitted MSB first.
- 10 bits per word.
- 200 words per frame.
- 2.665 frames per second.
- 50 words per subframe.
- 4 subframes per frame.
- 93.808625 msec per subframe.
- 375.2345 msec per frame.
- 1.8761725 msec per word.
- 187.61725 msec per bit.
- 0.0888 kbpi packing density at 60 ips.
- The following operational modes are available:
  - a. In-Track Non-Contiguous (ITNC).
  - b. Cross-Track Non-Contiguous, Left (CTNC-Left).
  - c. Cross-Track Non-Contiguous, Right (CTNC-Right).
  - d. Cross-Track Non-Contiguous, Left/Right (CTNC-Left/Right).
  - e. In-Track Contiguous (ITC).
  - f. Cross-Track Contiguous (CTC) Rad only.
  - g. Cross-Track Contiguous (CTC) Scat only.
  - h. Cross-Track Contiguous (CTC) Rad and Scat.

Table 3.6-2

S-193 Rad/Scat Measurement List

Measurement Name	No. of Bits	Samples Per Frame
Bilevel Word 2	10	1
W.G. Cal. Switch Pos.	1	1
Spare, Set to 0	1	1
Roll Deriv. Pos. CMD	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
SCAT Ready	1	1
ALT. Ready	1	1
Bilevel Word 3	10	1
RAD Ready	1	1
ALT. Unlock	1	1
Trans. Overheat	1	1
Rec. Malfunction	1	1
Gimbal Malfunction	1	1
Trans. Malfunction	1	1
Receiver Overheat	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Ground, Set to 0	1	1
Spare	10	1

Measurement Name	No. of Bits	Samples Per Frame
Spare	10	1
Crystal Oscillator Oven Temp. Control Pwr.	10	1
REF T2 Temp - Low	10	1
REF T1 Temp - High	10	1
SCAT TWTA Final Temp	10	1
Spare	10	1
SCAT TWTA Helix Temp	10	1
Spare	10	1
Pitch CMD Position	10	1
Roll CMD Position	10	1
Pitch Torq. Current	10	1
Roll Torq. Current	10	1
Spare	10	1
-10 Volt Pot Supply (IEP)	10	1
Spare	10	1
Chassis	10	1
SCAT TWTA Heater Voltage	10	1
Driver TWT Helix Voltage	10	1
Driver TWT Heater Voltage	10	1
SCAT TWT Collector Current	10	1
SCAT TWTA Helix Current	10	1
SCAT TWTA Helix Voltage	10	1
Driver TWT Cathode Current	10	1
OOA Pitch Bias	10	1
Pitch Shaft Temp No. 2	10	1
RF Oven Base Temp (Expanded) No. 3	10	1
Feed Temp. (Antenna)	10	1
Input Waveguide Temp.	10	1
RAD Proc. Internal Temp.	10	1
Driver TWT Temp.	10	1
TDA DI Voltage	10	1
OOA Roll Bias	10	1
Reg. Servo Bus Voltage	10	1
Driver TWT Helix Current	10	1
Bilevel Word 1	10	1
Pitch Int. Reset CMD	1	1
Roll Int. Reset CMD	1	1
Clock Present	1	1
Data Valid Flag	1	1
Pitch + Accel. CMD	1	1
Pitch - Accel. CMD	1	1
Roll + Accel. CMD	1	1
Roll - Accel. CMD	1	1
Pitch Deriv. Pos. CMD	1	1
Spare, Set to 0	1	1

Measurement Name	No. of Bits	Samples Per Frame
Sync Word 1	10	4
Sync Word 2	10	4
Sync Word 3	10	4
Subframe ID Word	10	4
Subframe ID	9	4
Status Word 1	10	20
SCAT Amplifier Gain	2	20
Meas. Angle Number	4	20
Scan Mode Bits	4	20
Status Word 2	10	20
SCAT Bandpass Filter/Integrator	2	20
RAD Status	2	20
SCAT Status	3	20
Data Presence/Absence	1	20
Polarization	2	20
Pitch	10	20
Roll	10	20
Data Word 1	10	20
Data Word 2	10	20
Spare	10	1
Roll Housing Temp. No. 1	10	1
Roll Housing Temp. No. 2	10	1
Roll Shaft Temp. No. 1	10	1
Roll Shaft Temp. No. 2	10	1
Pitch Housing Temp. No. 1	10	1
Pitch Housing Temp. No. 2	10	1
RAD AGC Integrator Output	10	1
Pitch Shaft Temp. No. 1	10	1
RF Oven Base Temp. No. 1	10	1
RF Oven Base Temp. No. 2	10	1
SCAT Proc. Internal Temp.	10	1
Bi-phase Modulator Base Temp.	10	1
Spare	10	1
Spare	10	1
+5V IEP Converter Supply	10	1
RF Oven Base Temp (Expanded) No. 4	10	1
Reflector Temp (Antenna) No. 1	10	1
Reflector Temp (Antenna) No. 2	10	1
+15V IEP Supply	10	1
Spare	10	1
+12.6 IEP Supply	10	1
Boost Reg. Temp	10	1
Pitch Pwr. Ampl. Temp.	10	1
Roll Pwr. Ampl. Temp	10	1
SCAT Proc. Temp (External)	10	1

Table 3.6-3

S-193 Altimeter Data Format Characteristics

- The data stream modulates a VCO to produce an output signal on IRIG D. This signal is mixed with IRIG 13 (S194) and IRIG B (S190A) signals and recorded redundantly on tracks 14 and 15 of the EREP tape recorder.
- PCM, NRZ-L, 10 kbps, Transmitted MSB first.
- 10 bits per word.
- 1,040 words per frame.
- 20 words per subframe.
- 52 subframes per frame.
- 0.9615 frame per second.
- 1.04 seconds per frame.
- 1 msec per word.
- 100 μsec per bit.
- 0.167 kbpi packing density at 60 ips.
- Five modes of operation are available:

  Mode I - Pulse shape experiment.
  Mode II - Cross section experiment.
  Mode III - Time correlation experiment.
  Mode V - Pulse compression-10 nsec.
  Mode VI - Nadir align.

Consideration of the operating scan mode rates and the data rates summarized in Tables 3.6-1 and 3.6-3 leads to the conclusion that the non-RF circuits and functions are at least rate compatible with the NIM-CAMAC approach. It can also be observed that because most of the non-RF circuits are digital, CAMAC implementation is most desirable. The radiometer processor circuit, shown in Figure 3.6-4, is the most marginal but it could be implemented into a special design CAMAC card. This card would have both analog input and output via front panel connectors; however, processor control from the DHCU would be by way of the CAMAC Dataway.

Table 3.6-4

S-193 Altimeter Measurement List

This table provides a complete list of all of the measurements output by the S-193 Altimeter. Included in the list is the number of times the measurement will appear in each frame, its location, the number of PCM bits in the measurement, and the measurement number used to identify the measurement. Generally, each measurement is assigned one unique measurement number. However, due to the nature of the data in the sample and hold gate parameters, it is necessary to identify this data in four different ways; as one measurement, as two measurements, and as 16 measurements. The user is cautioned that these four identifications all apply to the same data and, therefore, only one method of identification should be used at a time.

Measurement Name	No. of Bits	Sample Per Frame
Frame Sync	10	1
Frame Sync	10	1
Frame Sync	10	1
Sample/Hold No. 1-16 as one measurement	10	832
Sample/Hold No. 1-8 as one measurement	10	416
Sample/Hold No. 9-16 as one measurement	10	416
Note: This data originates from the same eight sample & hold gates as A104-293 but at a different time and represents the second sample from each gate per data frame.		
Sample/Hold No. 1*	10	52
Sample/Hold No. 2*	10	52
Sample/Hold No. 3*	10	52
Sample/Hold No. 4*	10	52
Sample/Hold No. 5*	10	52
Sample/Hold No. 6*	10	52
Sample/Hold No. 7*	10	52
Sample/Hold No. 8*	10	52
Sample/Hold No. 9*	10	52
Sample/Hold No. 10*	10	52
Sample/Hold No. 11*	10	52
Sample/Hold No. 12*	10	52
Sample/Hold No. 13*	10	52
Sample/Hold No. 14*	10	52
Sample/Hold No. 15*	10	52
Sample/Hold No. 16*	10	52
Sample/Hold No. 1 & 9**	10	104
Sample/Hold No. 2 & 10**	10	104
Sample/Hold No. 3 & 11**	10	104
Sample/Hold No. 4 & 12**	10	104
Sample/Hold No. 5 & 13**	10	104
Sample/Hold No. 6 & 14**	10	104
Sample/Hold No. 7 & 15**	10	104
Sample/Hold No. 8 & 16**	10	104

Measurement Name	No. of Bits	Sample Per Frame
Status Word - word 20	10	52
Subframe Counter	6	52
Frame Counter (Subframe 1, word 20, bits 7-10 and subframe 2, word 1, bits 1-2)	6	1
Status Word (Subframe 2, word 1)	10	1
Sub3 mode (Bits 3-5)	3	1
Sub2 mode (Bits 6-8)	3	1
Sub Mode (Subframe 2 word 1 bits 9-10 and subframe 2 word 2 bits 1-4)	6	1
Status Word (Subframe 2 wd 2)	10	1
Mode (Bits 5-10)	6	1
Pitch Gimbal Position	10	1
Altitude 8	20	1
AGC Control Voltage	10	1*
A060-193 Driver TWT Helix Current	10	1
AGC Avg. Detector Power Level	10	1
A049-193 Driver TWT Cathode Current	10	1
Time Disc Temp	10	1
A050-193 00A Pitch Bias	10	1
Rec. Temp	10	1
A051-193 Pitch Shaft Temp	10	1
Noise Gate Integrated Voltage	10	1
Altitude 1	20	1
Ramp Gate Integrated Voltage	10	1
A052-193 RF Oven Base Temp	10	1
Plateau Gate Integrated Voltage	10	1
A053-193 Feed Temp (Antenna)	10	1
A054-193 Input Waveguide Temp	10	1
A055-193 Rad Proc. Internal Temp	10	1
Altitude 2	20	1
A056-193 Driver TWT Temp	10	1
Roll Gimbal Position	10	1
A057-193 TDA DI Voltage	10	1
A058-193 00A Roll Bias	10	1
RAD/SCAT Bilevel 1	10	1

Measurement Name	No. Bits	Samples Per Frame
Pitch Int. Reset CMD	1	1
Roll Int. Reset CMD	1	1
Clock Present	1	1
Data Valid Flag	1	1
Pitch + Accel. CMD	1	1
Pitch - Accel. CMD	1	1
Roll + Accel. CMD	1	1
Roll - Accel. CMD	1	1
Pitch Deriv. Pos. CMD	1	1
Spare, Set to 0	1	1
AGC Control Voltage	10	1*
RAD/SCAT Bilevel 2	10	1
W.G. Cal. Switch Pos.	1	1
Spare, Set to 0	1	1
Roll Deriv. Pos. CMD	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
SCAT Ready	1	1
ALT. Ready	1	1
RAD/SCAT Bilevel 3	10	1
RAD Ready	1	1
ALT. Unlock	1	1
Trans. Overheat	1	1
Rec. Malfunction	1	1
Gimbal Malfunction	1	1
Trans. Malfunction	1	1
Receiver Overheat	1	1
Spare, Set to 0	1	1
Spare, Set to 0	1	1
Ground, Set to 0	1	1
RAD/SCAT Bilevel 4	10	1
Altitude 3	20	1
A059-193 Reg. Servo. Bus Voltage	10	1
Altitude 4	20	1
AGC Control Voltage	10	1*
Altitude 5	20	1
Altitude 6	20	1
AGC Control Voltage	10	1*
Altitude 7	20	1

*Sample/Hold No. 1 through 8 represent the first sample from each respective gate per data frame. Sample/Hold No. 9 through 16 are the second sample from each respective gate per data frame. This is identified by a 1 and 2 in the first position of the sequence field in the measurement number. The second position in this field gives the gate number.

**This set of measurement numbers identify both samples out of each respective gate as the same measurement. The data are uniquely identified in this fashion by a 3 in the first position in the sequence field of the measurement number and the gate number in the second position.

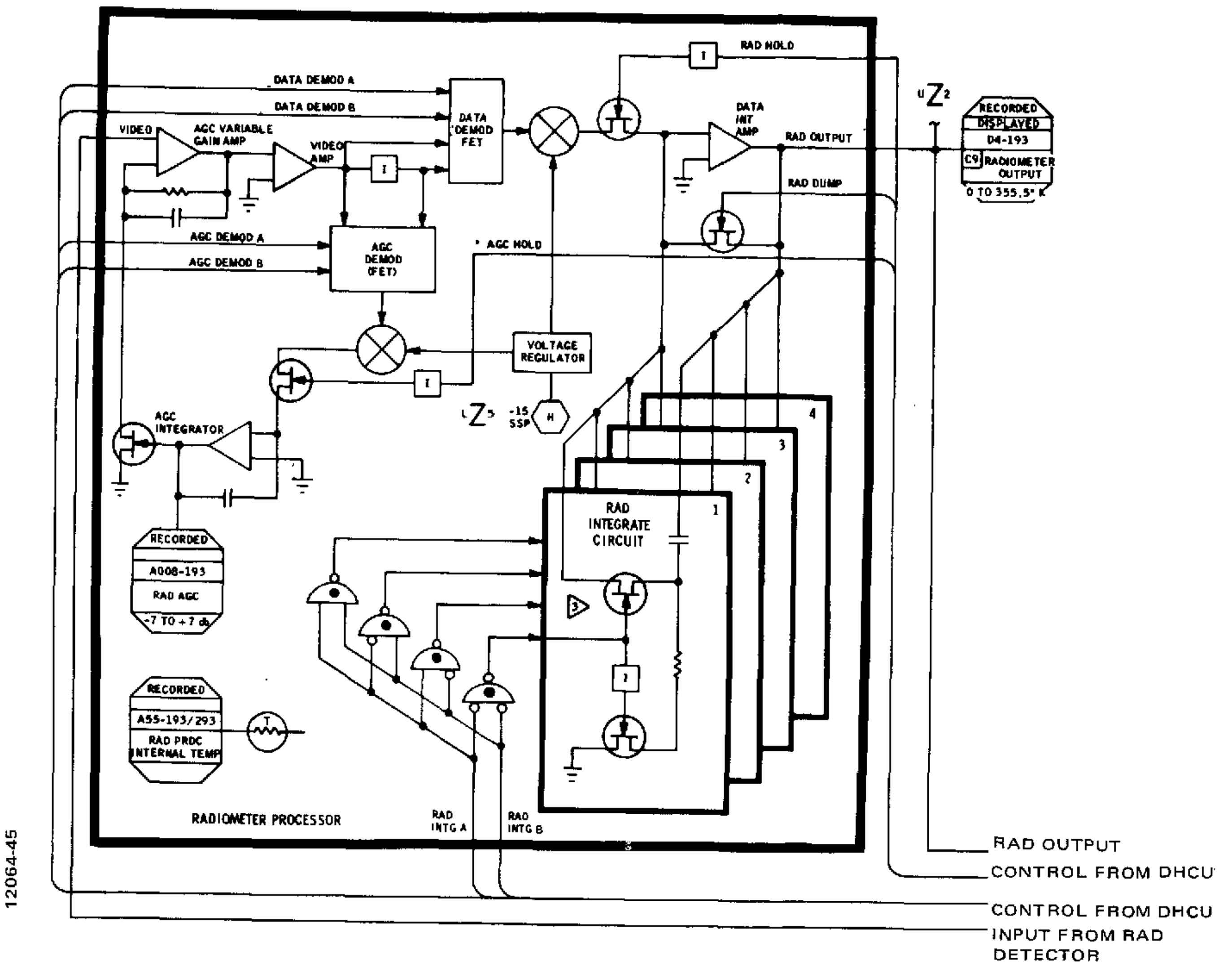

Figure 3.6-4 Radiometer Processor Circuit

Figure 3.6-5 shows the Data Handling Control Unit (DHCU). All of the DHCU digital functions would be accomplished in the digital computer. Input of digital signals is by way of one-half of a dual 24-bit input gate. Input of analog signals is through three double-width CAMAC analog data system modules. Each of these analog data system modules contains 16 differential analog inputs, a random address multiplexer, and a 12-bit A/D converter. DHCU output functions are via a 24-output line driver module. Data output from the DHCU to the tape recorder is through the Dataway to a special CAMAC card containing a data buffer, parallel-to-serial converter, and a voltage controlled oscillator (VCO).

The altimeter sample and hold and AGC detector shown in Figure 3.6-6 is not amenable to implementation in standard modules but could be packaged in a double-width CAMAC module. By including the analog multiplexer and A/D converter from the digital interface and control unit (shown in Figure 3.6-7) in this module, the interface between these two units is the CAMAC Dataway. The remainder of the digital interface and control unit is implemented in software in the computer. Similarly, the digital functions of average altitude computation, shown in Figure 3.6-6, mode select and command generation and altimeter nulling shown in Figure 3.6-8, are performed in the computer. Digital input from non-CAMAC equipment is via one-half of a dual 24-bit input gate and output is via a 24-output line driver.

Replacement of the antenna positioning torque motors with stepping motors and the feedback pots with shaft position encoders enables the implementation of the antenna servo amplifiers with CAMAC units. The CAMAC modules required are two stepping motor drives, two position encoders, and one interrupt register.

3.6.3 NIM-CAMAC Applicability Summary

Major elements of the S-193 instrument consist of RF components in the 500-MHz to 14-GHz region. These RF components are not available in NIM and CAMAC, and they are not compatible with NIM-CAMAC packaging. All other components of the instrument comprising the data collection and formatting, antenna control, mode control, and command and monitoring can be implemented using the CAMAC approach. Table 3.6-5 lists the specific CAMAC modules recommended for S-193 implementation. Table 3.6-6 provides a weight and power summary for the NIM-CAMAC and Skylab implementations.

3.6.4 References

The references to Skylab EREP S-193 used in preparation of Section 3.6 are listed in Section 3.5.4.

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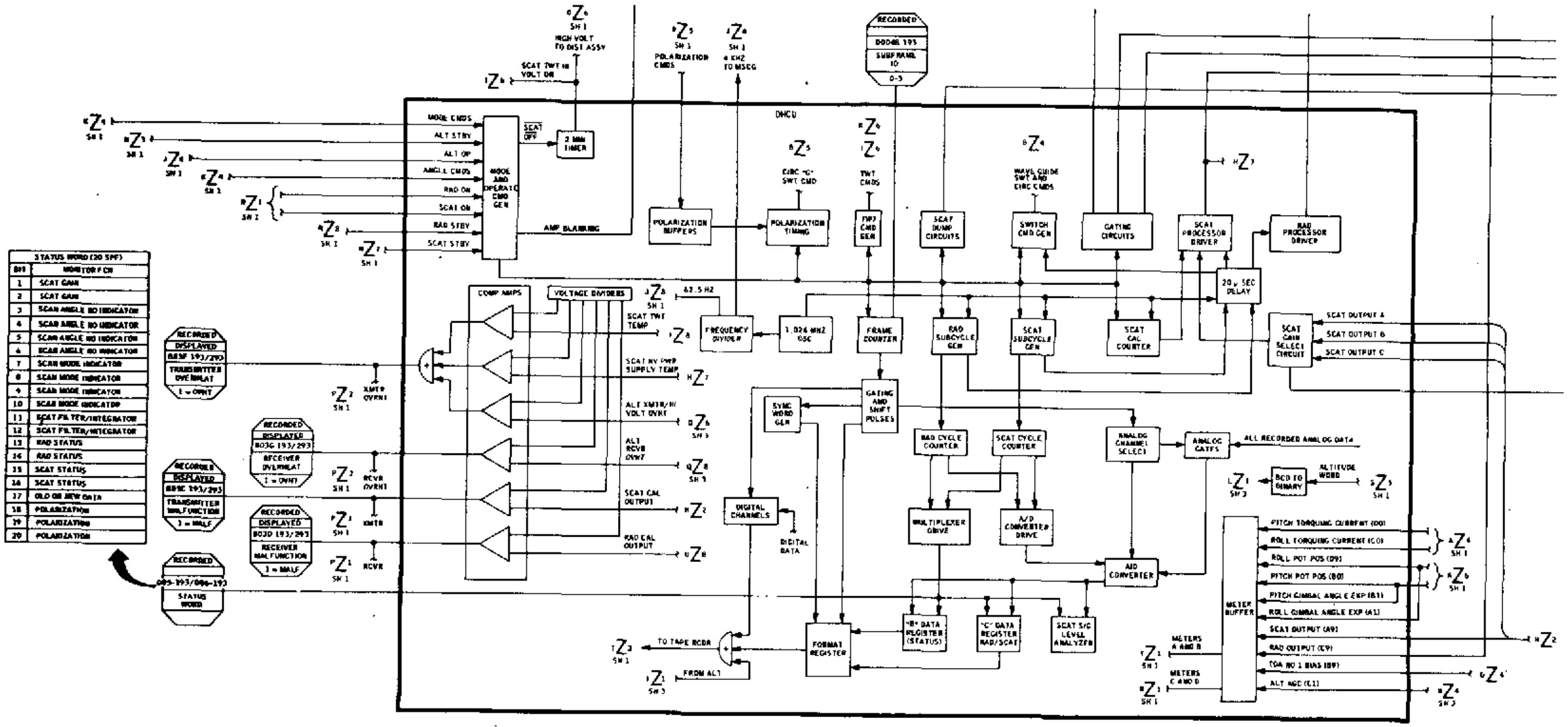

Figure 3.6-5 Data Handling Control Unit Circuit

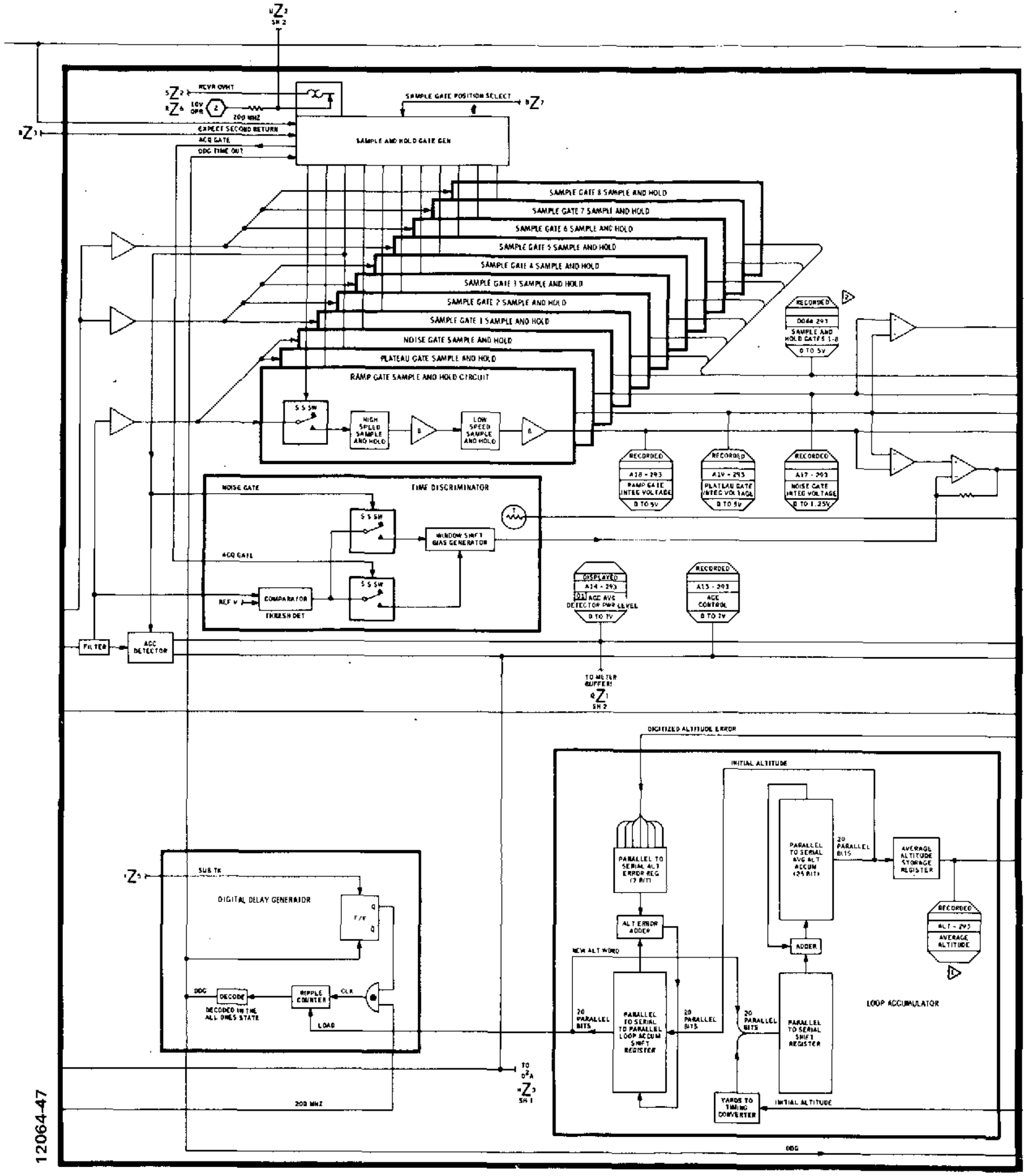

Figure 3.6-6 Altimeter Sample and Hold and AGC Circuit

FOLDOUT FRAME 1

FOLDOUT FRAME 2

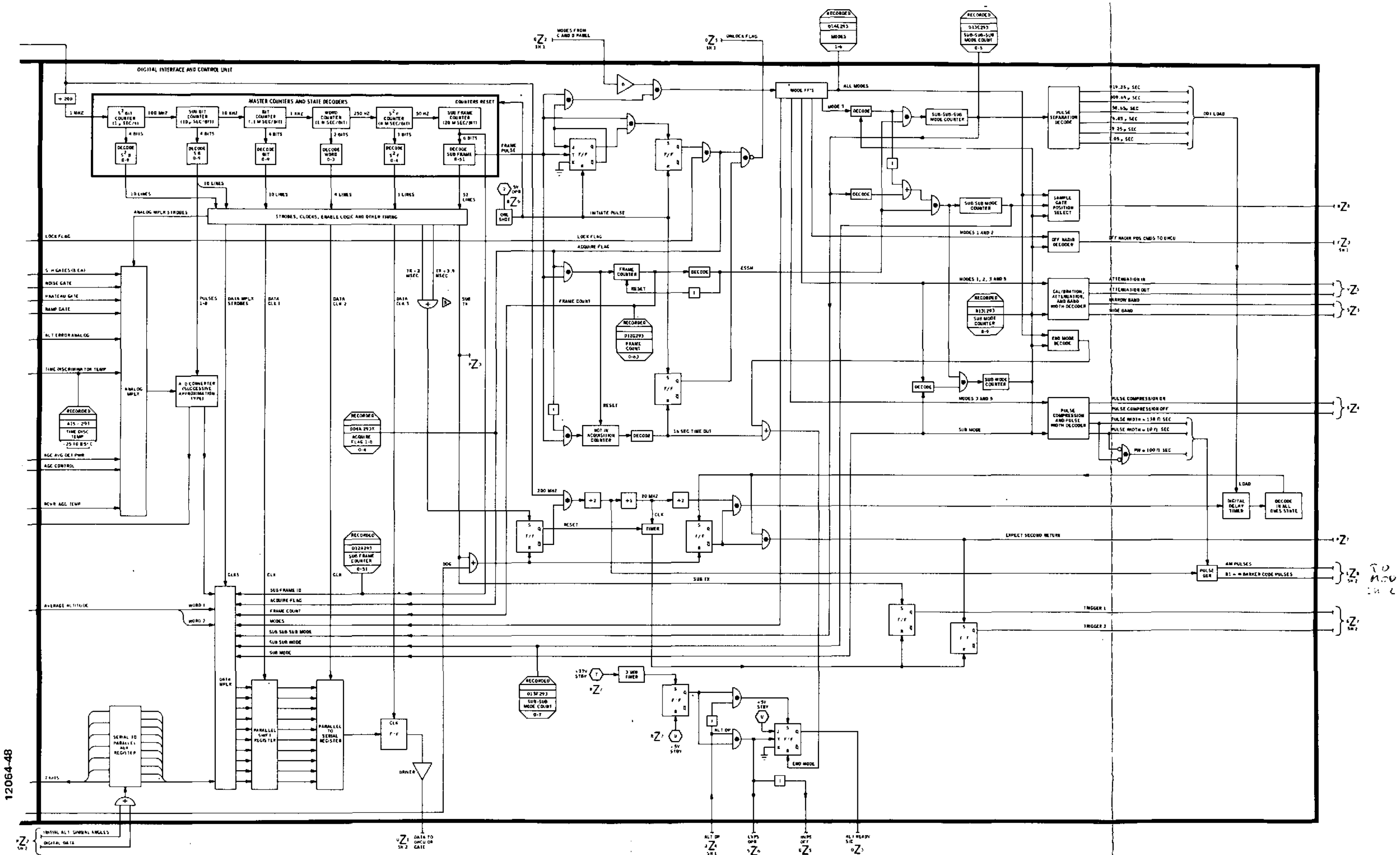

Figure 3.6-7 Digital Interface and Control Unit

FOLDOUT FRAME 1

FOLDOUT FRAME 2

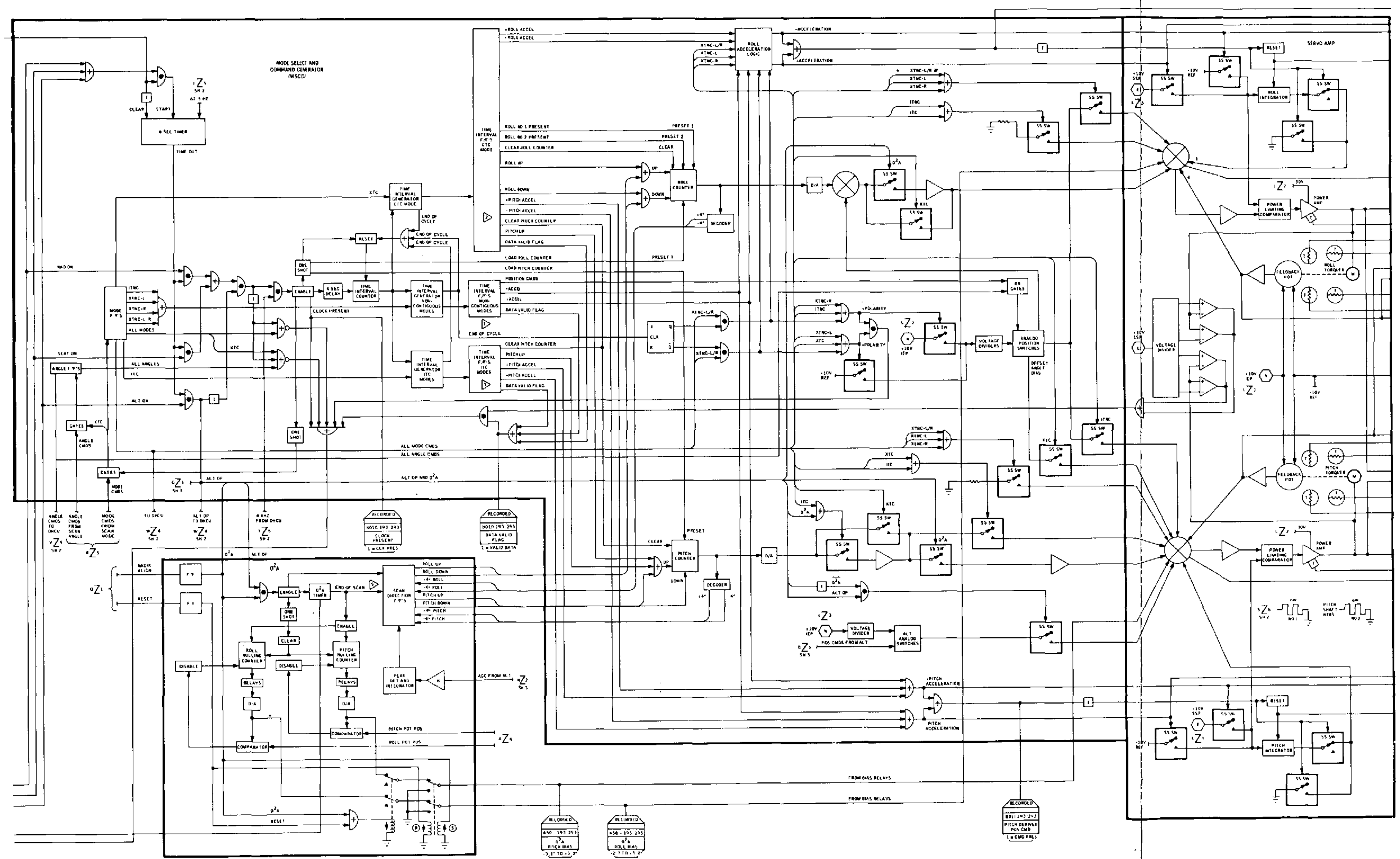

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Figure 3.6-8 Mode Select and Command Generator, Servo Amplifier, and Altimeter Nulling Circuits

Table 3.6-5

Standard CAMAC Modules Used in S-193

CAMAC Modules	Weight (kg)	Power (W)	Cost ($)
Branch Driver BD011[a]	11.4	60	4,800
Crate MC 100[a]	22.7	130	1,545
Crate Controller CC101[a]	1.4	12	1,350
Terminator BT-01[b]	0.1	1.8	275
24-Bit Input Gate (2) 3420[b]	1.0	11.4	710
32-Channel Analog System (3) 5301[c]	3.0	24	4,500
24-Bit Output Register (2) 3072[b]	1.0	11.4	850
Position Encoder PE019[a]	0.8	6.6	790
Stepping Motor Controller (2) 3361[b]	2.0	20.0	1,450
Interrupt Register IR026[a]	0.8	2.9	395

( ) Numbers in parentheses refer to number of modules.

(a) Manufactured by EG&G/Ortec.

(b) Manufactured by Kinetic Systems.

(c) Manufactured by Bi Ra Systems.

Table 3.6-6

S-193 Weight and Power Summary

I. NIM-CAMAC Implementation

Component	Weight (kg)	Power (Watts)
PDP-11/35 Computer	91	150
DEC Tape and Controller	41	870 [a]
Terminal - Display and Keyboard	27	130
CAMAC Crate and Electronics	33	220
Branch Driver	11.4	60
Non-NIM-CAMAC Electronics	46	100
Antenna	46	
Additional Cables	5	
Total	300	660

II. Skylab Implementation

Component	Weight (kg)	Power (Watts)
Antenna and Electronics	122	300
Control and Display Panel	46 est	100 est
Total	168	400

[a] Required only during program change for new instrument or mode modification.

SECTION 4

NIM-CAMAC EQUIPMENT IDENTIFICATION

This section contains descriptions of all standard modules used in implementing the various payloads studied. The frequency of use of these modules is shown in Tables 4-1 and 4-2. The following pages of this section consist of the manufacturer's specification sheet for each module. The specification sheets are organized first alphabetically by manufacturer's name, then alphabetically and in numerical sequence by model number.

Table 4-1

Frequency of Use (CAMAC Module)

CAMAC Module	Payload: Astronomy	Atmospheric	Auroral	Cosmic Ray	Scanner	Microwave
Crate/Pwr Sup	2	4	3	1	1	1
Type A Controller	2	4	3	1	1	1
Branch Driver	1	2	2	1	1	1
8-Input/8-bit PHD				1		
4-Input/10-bit PHD			1	1		
8-Input/12-bit Scaler				2		
Quad Scaler			1	1		
Real-Time Clock	2	2	3	1		
Timer Module			1			
10-MHz Clock	1					
Interrupt Register	3	4	2	1	1	1
Octal D/A Converter	2		6	1		
Quad Time Digitizer				2		
32-Input A/D		1	3	1	1	3
24-Line Output Register	5		5	1	1	1
24-Line Input Register	2		1	1	1	2
Differential Input Register		7				
Differential Output Register		18				
12-bit Output Register				1		
Motor Controller		9			1	2
Dual Preset Scaler	5		3			
Position Encoder	8	8	3		1	1
Point Plotter	1		2	1		
Character Generator	2		2	1	1	
Vector Generator	1					
Display Driver	2		2	1	1	
Panel Interface	2		2		1	
Terminator	1	2	2	1	1	1

Table 4-2

Frequency of Use (NIM Module)

NIM Module	Astronomy	Atmospheric	Auroral	Cosmic Ray	Scanner	Microwave
NIM Bin	1		4	3		
Dual Amp				1		
Quad Amp				1		
Dual Fan In				1		
Dual Fan Out				2		
Quad Disc				1		
Const. Frac. Disc				8		
High Voltage Power	2		7	8		
Preamp/Amp			6			
Amp			5			

Bi Ra Systems, Inc.

Model 5301

Analog Data System

The Model 5301 is a double-width CAMAC module that contains a complete 12 bit Analog Data System, with 32 single-ended or 16 differential channels. The inputs are jumper selectable for eight ranges.

0 to +10V
0 to 10.24V (2.5mv bit)
-10V to +10V
-10.24V to 10.24V (5mv bit)

0 to+5V
0 to +5.12V (1.25mv bit)
-5 to +5V
-5.12 to +5.12V (2.5mv bit)

The model 5301 can run in three different modes: random addressing, sequential addressing, and repetitive single-channel addressing. All modes run with or without LAM's. Single channel repetitive total time for conversion is<10 micro sec. Other modes take <20 micro sec. The module can be expanded to 128 single-ended or 64 differential channels with the Model 5101 Analog Mux Module, 32/16 channels per Mux.

The Model 5301 has the following commands:

COMMAND	ACTION
F(0) . A(0)	Read ADC & Address Q if end of convert.
F(2) . A(0)	Same as F(0) . A(0) plus inc address and start new conversion.
F(2) . A(1)	Same as F(0) . A(0) plus start new conversion, same channel.
F(8) . A(15)	Test L. Q if end of convert and LAM enable are set.
F(10) . A(15)	Clear end of convert.
F(16) . A(0)	Write address and start convert.
F(24) . A(0)	Reset run.
F(24) . A(15)	Reset LAM enable.
F(26) . A(0)	Set Run.
F(26) . A(15)	Set LAM enable.
F(27) . A(15)	Test end of convert Q if done.
Z . S2	Clears address register, run, LAM enable and end of convert.

3520 D Pan American Freeway, N.E. Albuquerque, NM 87107 505/345-5864

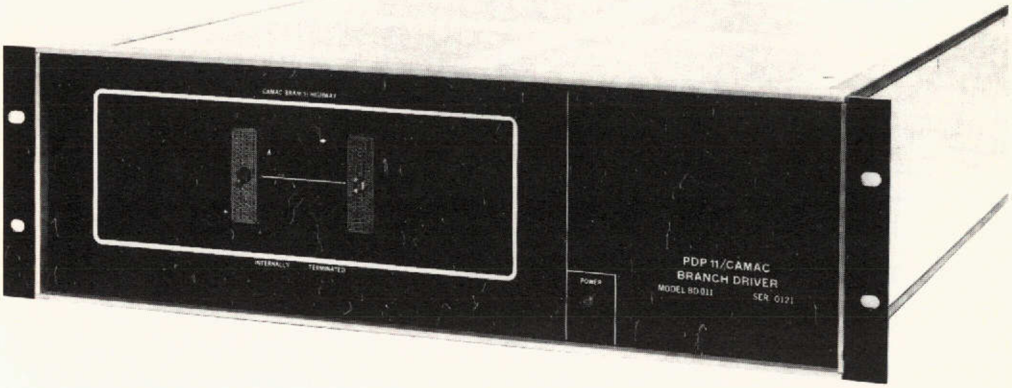
EG&G

CAMAC

BD011 Branch Driver

Technical Data

March 1972



The BD011 Branch Driver is designed to perform the interfacing functions between the Digital Equipment Corporation PDP11 computer and a CAMAC Branch Highway. All signal levels and timing conform fully to the requirements of Specification EUR 4600e for CAMAC systems. Designed for easy integration into any PDP11 peripheral configuration, the BD011 extends the flexibility of the CAMAC concept into the computer, and provides a rapid and economical means of achieving an integrated computer-based data logging and control system.

As a system element, the BD011 can support up to and including seven CAMAC crates, and multiple BD011's may be integrated into a single PDP11-based system. The Branch Driver is configured to take maximum advantage of the addressing structure, software complement and timing flexibility of the PDP11.

The BD011 is designed to be both versatile and compact, and is packaged complete with power supply, in a 5-1/4" high, 19" wide rack-mountable chassis. Connection to the CAMAC Branch Highway is provided by two Hughes 132-pin connectors; however, the BD011 can be equipped with as many as seven Hughes connectors, if desired. This design flexibility allows the BD011 to be used in the Alternate Branch Highway Configuration described in Specification EUR 4600e.

Internal termination is provided for the Branch Highway which, when desired, can be quickly connected by the user to the connector array. This allows the BD011 to be placed in the most desirable location for the specific system, either in the middle or at the end of a CAMAC crate array.

Consistent with PDP11 systems, the registers within the BD011 which would logically be loaded in sequence occupy sequential word addresses. Bits in the Control/Status Register which are monitored most frequently are positioned so that test instructions may be used directly. LOOK-AHEAD "data chaining" techniques allow multiple contiguous data sources within a crate to be treated as a single block of data, with minimum time and housekeeping penalty.

EG&G NUCLEAR INSTRUMENTATION DIVISION
500 MIDLAND ROAD, OAK RIDGE, TENNESSEE 37830
PHONE (615) 482-4411
TWX 810-572-1078
TELEX 055-7450

Printed in U.S.A.

1443 10K 0372

Data transfer to/from the BD011 can be performed either address-to-address under program control or via DMA under control of the BD011. Provision for interrupt upon completion of DMA transfer as well as internal Branch Driver status is provided, and can be inhibited and monitored via software. The BD011 is unambiguous between DMA (NPR request) and Interrupt (BR 7:4).

The BD011 has the advantage of being an independent or "stand alone" unit, which allows hardware system installation and debugging to be performed in a nearly ideal incremental fashion, greatly aiding the fast isolation of system faults. The overall system environment was also considered in design details: – for example, the BD011 "power on" indicator is located in the output circuitry, thus verifying power supply status during testing and operation, rather than functioning as the usual AC indicator.

Inputs Logical Ø = +2.4V to +5.5V
Logical 1 = Ø V to +1.2V
Logical Ø = requires ≤ .3 mA in
Logical 1 supplies ≤ 1.6 mA out

Outputs Logical 1 = Ø to 0.5V
Logical 1 ≥ 127 mA sink

All outputs are intrinsic wired OR.

TIMING

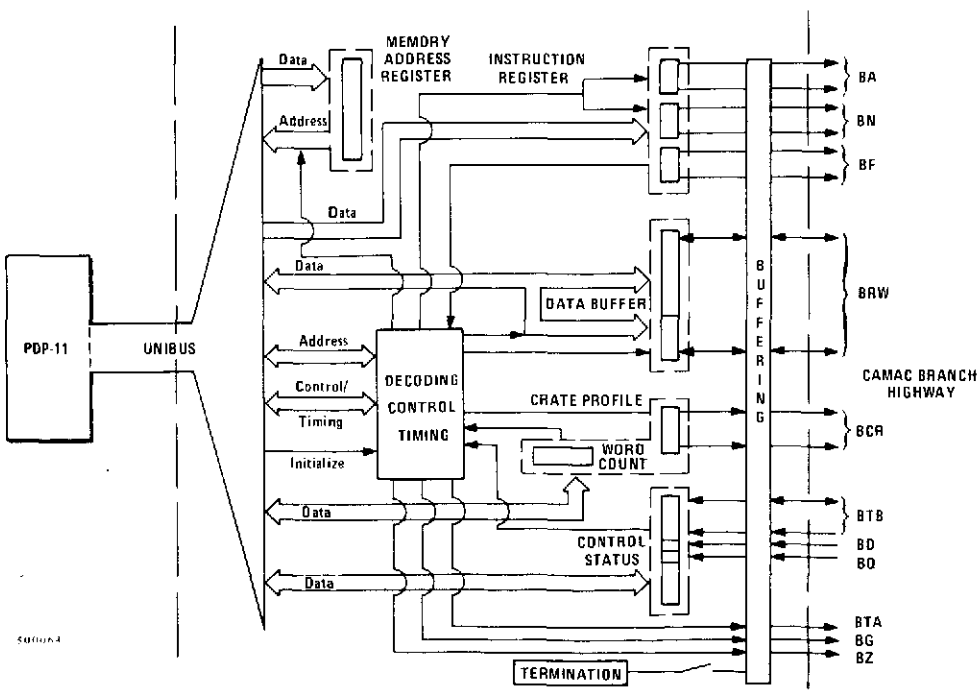
The BTA transition will only occur when BD011 output conditions are stable. Sequential Branch Highway operations will be initiated only when all Crate Dataway operations are complete (all $BTB_i = 1$). Internal deskewing times are adjustable over a range of 50 nsec to 190 nsec; range shift/extension requires component change. BTA transitions are conditioned to provide rise times/fall times of 100 nsec ± 50 nsec. BTB transitions are integrated (without degrading signal cable characteristics) to provide rise times/fall times of 100 nsec ± 50 nsec.

COMPUTER INTERFACE

The BD011 appears as 5 sequential addresses to the PDP11. In addition, if so conditioned, the BD011 may generate 2 levels of Bus requests: NPR-DMA transfer; BR7:4 (hardware selectable), to generate Interrupt Requests. The BD011 may occupy addresses in the range $760000_8/767777_8$ (expressed in 18-binary-bit PDP11 address format). The lowest address must have Ø for its low-order octade and as the PDP11 increments by 2, two BD011's connected to the same PDP11 may not occupy sequential addresses.

REGISTER ASSIGNMENT

I 76NNNØ Control/Status Register
II 76NNN2 Data Buffer Register
III 76NNN4 Memory Address Register
IV 76NNN6 Crate Select Word Count Register
V 76NN1Ø Instruction Register



Simplified Block Diagram of the BD011.

CONTROL/STATUS REGISTER

This address is a composite of read only (TCR, DONE, BQ, NEX, TO1, TO2, CRTO, BDDYN) and read/write (ABRT, BDSQ, TCRSQ, BDIE, TCRIE, RST) bits. Bits which cannot respond to the direction of transfer are not affected.

Bit No.	Mnemonic	Interpretation
15	TCR	Task Completion Ready; logical Or of DONE, NEX, and ABRT.
14	DONE	Is set by (1) PDP11 Initialize, (2) resetting ABRT under program control, and (3) BD011 completing an assigned task with no detectable error. BQ must be independently monitored to verify correct addressing.
13	BQ	Reflects status of Branch Highway BQ line during last CAMAC transfer.
12	NEX	No Execute; logical Or of TO1, TO2, and CRTO.
11	TO1	PDP11 time out; is set if BD011 has become Bus Master to transfer data via DMA and is unable to complete transfer.
10	TO2	CAMAC time out; is set if all addressed crates do not respond with normal BTB transitions.
9	CRTO	Crate Overflow; is set if BD011 is in Single mode (as determined by rear panel switch) and is unable to find sufficient valid CAMAC addresses to complete a DMA task.
8	ABRT	ABORT; is set if write is attempted into any register employed by BD011 in current task execution or into Data Register except to execute a PDT write. ABRT specifically indicates software error. ABRT must be reset before BD011 can execute a new task; it is reset by writing 0 into B8 of Control/Status Register and PDP11 Initialize.*
7	BDSQ	Branch Demand Sequencer; is set by false/true transition of Branch Highway BD line and is reset by (1) PDP11 Initialize, (2) executing a BD interrupt, (3) writing a 0 into B7 of Control/Status Register, or (4) writing a 1 into B8 of a GL operation.*
6	BDDYN	Branch Demand Dynamic; reflects state of Branch Highway BD line.
5	TCRSQ	Task Completion Ready Sequencer; is set by false/true transition of TCR and reset by (1) Task Initiation, (2) executing a TCR interrupt, (3) PDP11 Initialize, or (4) writing a 0 into B5 of Control/Status Register.*

(continued)

Bit No.	Mnemonic	Interpretation
4		Unassigned; reads as 0.
3	BDIE	Branch Demand Interrupt Enable; is set by writing 1 into B3 of Control/Status Register or by PDP11 Initialize; is reset by writing 0 into B3 of Control/Status Register. If BD interrupt is pending (BDSQ and BDIE) when BDIE is reset, Bus Request will be withdrawn. If BDIE is set when BDSQ is set, Bus Request will be initiated.
2	TCRIE	Task Completion Ready Interrupt Enable; is set by writing 1 into B2 of Control/Status Register and is reset by writing 0 into B2 of Control/Status Register or by PDP11 Initialize. If TCRIE is reset when a TCR interrupt is pending (TCRSQ and TCRIE), Bus Request will be withdrawn. If TCRIE is set when TCRSQ is set, Bus Request will be initiated.
1		Unassigned; reads as 0.
0	BZG	BZ Generate; causes a 20-μsec Branch Highway BZ pulse to be generated when a 1 is written into B0 of Control/Status Register. B0 will read as 1 for duration of BZ pulse and is then reset to 0.

*These bits will read as 1 in response to a UNIBUS DATIP transfer to avoid inadvertent resetting when operating on other bits of the word/byte.

DATA BUFFER REGISTER

This 24-bit register may be loaded/read once or twice (as specified in the Instruction Register) from the PDP11 effecting the 16/24 bit conversion if desired. The first load/read will transfer the least significant 16 bits; the second will transfer the most significant 8 bits.

MEMORY ADDRESS REGISTER

This 16-bit register specifies the affected Memory Address into/out of which data will be transferred via DMA. This register is considered to contain a valid address when the Instruction Register is loaded.

CRATE SELECT/WORD COUNT

The low order 9 bits of this register are interpreted as the number of CAMAC words to be transferred (2's complement form). The state of this register when the Instruction Register is loaded discriminates between DMA and Programmed Data Transfers: DMA: Word Count ≠ Ø; PDT: Word Count = Ø. The high order 7 bits of this register specify the crate(s) selected for transfer (BCR lines).

INSTRUCTION REGISTER

The least significant 4 bits specify the beginning Module Sub-Address (BA lines); the next 5 bits specify the beginning Module Station Number (BN lines); the next 5 bits specify the Function (BF lines); the next bit specifies 16 or 24 bit transfers; and the high order bit inhibits incrementing Module Station Number on Module Sub-Address overflow during DMA transfers. Loading this address is considered a command to execute. If GL is present, all other parameters are ignored and the subsequent Data Highway transfer will load the Data Buffer with the GL profile contributions from all present crates and set the DONE bit in the Control/Status Register. If GL is not present, the Function Code is examined sufficiently to determine direction of transfer and data involvement. If no data is involved, the subsequent Branch Highway mand, set the DONE bit in the Control/Status Register; operation will execute the command, set the DONE bit in the Control/Status Register; the BQ bit will monitor the BQ line and reflect its status. If data is involved, the direction of transfer is established and the Word Count is examined to differentiate between Programmed Data Transfer (WC ≠ 0), and DMA (WC = 0).

ELECTRICAL AND MECHANICAL

Power Supplies
A choice of power supplies is available to enable operation from either 120 V, 60 Hz ac or 220 V, 50-60 Hz ac.

Power Requirements
120 V, 60 Hz ac, 0.5 A max;
220 V, 50-60 Hz ac, 0.25 A max.

Dimensions
5-1/4 in. by 19 in. by 18-1/2 in.
Additional clearance required behind the unit to allow for entry and connection of UNIBUS.

EG&G/ORTEC

HIGH ENERGY PHYSICS

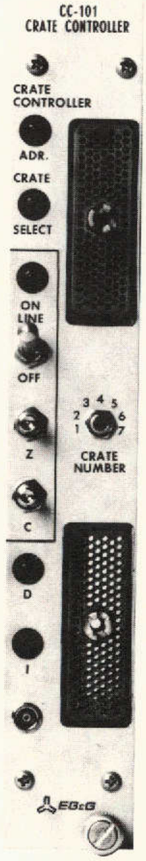
Technical Data

CAMAC

CC101
Crate Controller

July 1972

- BX generated from Dataway X-line
- Light emitting diodes (LED's) monitor status and functions
- On/Off line switch is a locking toggle switch



DESCRIPTION

The CC101 is a type A CAMAC crate controller designed to the latest specifications (EUR 4100e and EUR 4600e). It is packaged in a fully shielded double-width CAMAC module and occupies the control station and the adjacent normal station in a CAMAC crate. The CC101 functions as a logical interface between the Dataway and the Branch Highway. For CAMAC systems requiring more than one crate, a computer or a manual controller can be connected to the Branch Highway via a Branch Driver to select which CC101 is to transfer data to or from its crate. This arrangement also enables the particular crate to be interrogated concerning crate conditions.

Two 132-position front panel connectors wired in parallel propagate the Branch Highway information to and through the CC101. Branch Highway termination is made by means of an NID TC024 module.

Either On-Line or Off-Line operation can be selected by a mechanically locking switch on the front panel. In the On-Line mode the CC101 is logically connected to the Branch Highway, and the front panel C (clear) and Z (initialize) push-button switches are disabled.

In the Off-Line mode the CC101 does not interact with the Branch Highway in any way. Also, when in this mode, the C and Z switches are enabled, allowing these functions to be exercised within the crate without disturbing Branch Highway operations.

The CC101 has these features which make it an improvement over earlier crate controllers:

1. BX is generated from the Dataway X-line or in response to valid controller functions.

2. Light emitting diodes (LED's) monitor the On/Off line status, branch demand (BD-line), inhibit (I-line), crate select (BCR(i), i = position of front panel crate select switch), crate controller addressed (crate select and N = 28 or 30).

3. The On/Off line switch is a locking toggle switch, which means the crate can be remotely powered to the on-line state. A person does not have to depress a push button when the system is powered (e.g., after a power flicker).

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Other: ORTEC Incorporated, 100 Midland Rd., Oak Ridge, Tennessee 37830, Telephone (615) 482-4411, Telex 055-7450

The following CAMAC codes are used in the CC101:

Address N 28 (with S1; S2; B)

F(26)/ SAD 8	Generate Dataway Z returns Q = 0 X = 1
F(26)/ SAD 9	Generate Dataway C returns Q = 0 X = 1

Address N 30 (without S1; S2; B)

F(0)/ SAD 0 - 7	Read GL returns Q = 1 X = 1
F(16)/SAD 8	Load SNR returns Q = 1 X = 1
F(24)/ SAD 9	Remove Dataway I returns Q = 0 X = 1
F(26)/ SAD 9	Set Dataway I returns Q = 0 X = 1
F(27)/ SAD 9	Test Dataway I returns Q = 1 if I = 1; X = 1
F(24)/ SAD 10	Disable BD Output returns Q = 0 X = 1
F(26)/ SAD 10	Enable BD Output returns Q = 0 X = 1
F(27)/ SAD 10	Test BD Output returns Q = 1 if BD enabled; X = 1
F(27)/ SAD 11	Test Demand Present returns Q = 1 if demand presents; X = 1

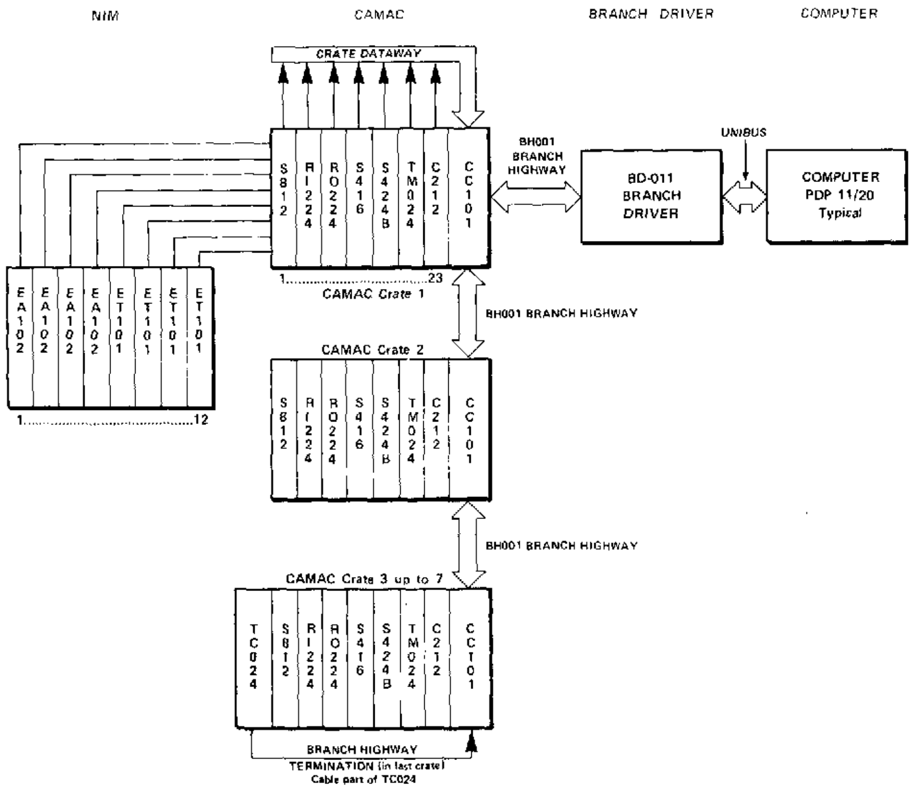
Station Number Codes

N1 to N23	Address one normal Station
N24	Address preselected normal Stations
N26	Address all normal Stations
N28	Address crate controller only
N30	Address crate controller without S1; S2; B
N0;25;27;29;31	Are reserved

TYPICAL APPLICATION

The following configuration illustrates a typical data-logging application.

Four ET101 modules located in a separate NIMBIN receive NIM Start and Stop pulses relating to experimental parameters. Their NIM-standard pulse-train outputs are counted and stored in the S812 Octal Scaler, which is mounted in a CAMAC crate. Under program control the PDP-11/20 issues the appropriate command to the Branch Driver to read the contents of the S812. The Branch Driver selects the appropriate CC101, commands it to couple the S812 to the Crate Dataway and to couple the Crate Dataway to the Branch Highway. When so selected, the CC101 propagates the Branch Highway command structure via the Crate Dataway to the S812, selecting one of its scalers for the content transfer. Subsequent similar operations transfer the contents of the other three scalers. The scalers may be reset after readout or on command, by means of software programs.



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EG&G/ORTEC

HIGH ENERGY PHYSICS

Technical Data

CAMAC
PP012, CG018, VG028, DD015 Modular Scope Display System

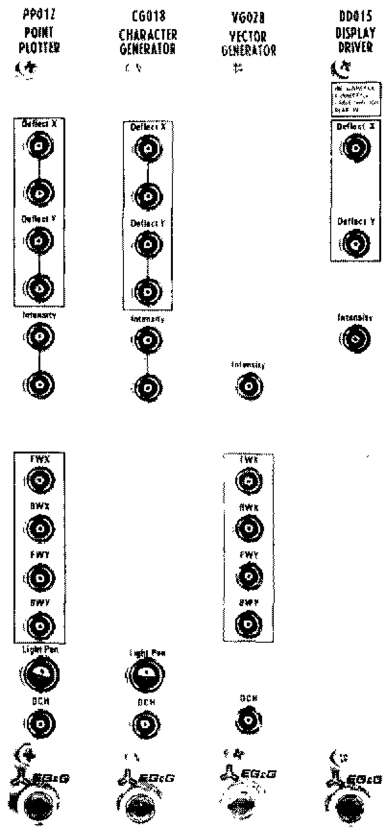
April 1973

The PP012 Point Plotter, CG018 Character Generator, VG028 Vector Generator, and DD015 Display Driver offer users of CAMAC systems a unique modular CRT display system with possibilities ranging from simple point-by-point plotting to elaborate alphanumeric display with automatic straight-line generation. Among other design criteria, modularity has been given great importance in order to allow users to purchase exactly the display functions they require, not more. (Incidentally, they also use exactly the crate stations required, not more.) Should the requirements grow, a more elaborate display system can be assembled at a later time.

All modules of the EG&G/ORTEC CRT display family are single-width CAMAC units. The modules are fully shielded by metal covers. The integrated circuit complement includes monolithic TTL and linear packages, hybrid digital-to-analog converters, and metal-oxide semiconductor (mos) large-scale arrays. The modules meet all electrical and mechanical specifications contained in TID-25875.

Several display functions provided by the modules and their combinations are given, and examples of system applications are shown.

- **1024-point resolution in both directions**
- **Command structure and logic for data transaction through direct memory channel, an essential feature with nonstorage oscilloscopes**
- **Efficient and uniform L-logic for slow writing speed of storage oscilloscopes**
- **Special module to drive Tektronix storage displays**
- **All-digital vector generation for accuracy and stability**
- **Simple summation of deflection and unblanking signals in multimodule arrangements**
- **Match almost all commercial CRT display instruments**
- **Built-in logic for light pen**



MODULES REQUIRED FOR TYPICAL DISPLAY FUNCTIONS

Display Functions	Modules Required
Simple x-y plots	PP012
y versus x, automatic stepping in the x direction	PP012
Pure alphanumeric	CG018
Curves or histograms with labels, titles, or text	PP012 and CG018
Graphics involving automatic straight-line generation	PP012 and VG028
Elaborate graphics with text	PP012, VG028, and CG018

The DD015 is used with any of the above configurations if a storage oscilloscope is used.

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Other: ORTEC Incorporated, 100 Midland Rd., Oak Ridge, Tennessee 37830, Telephone (615) 482-4411, Telex 055-7450

SYSTEM DESCRIPTION

COMPOSITE SYSTEM OPERATION

Only the interaction of the modules is described here. The individual units are described in following sections. The basic display module, the PP012, is essentially built around an x- and a y-register connected to digital-to-analog converters. These registers are organized as up-down counters. The VG028 Vector Generator produces two pulse bursts, whose rates and directions represent the velocity components of the spot motion. These pulse bursts are conducted to the up-down counters in the PP012 through front panel connections. The following two basic examples show how the two modules work together:

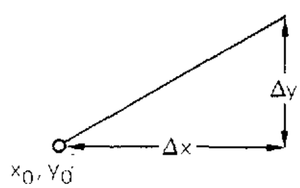
A straight segment (a vector) with origin x_0, y_0 and components Δx, Δy is obtained through the following steps:

Load the x-register of the PP012 with x_0.

Load the y-register of the PP012 with y_0.

Load the Δx-register of the VG028.

Load the Δy-register of the VG028, automatically starts and unblanks.



A polygonal line requires only one origin setting:

Load x_0 into PP012.

Load y_0 into PP012.

Load Δx_1 into VG028.

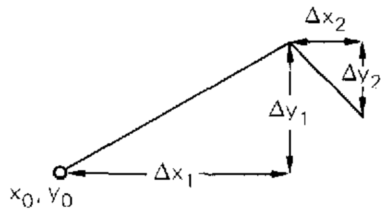
Load Δy_1 into VG028; start.

Wait for completion; then:

Load Δx_2 into VG028.

Load Δy_2 into VG028; start.

Wait . . . .



The CG018 Character Generator is a stand-alone module, but it can also be used with the basic PP012 Point Plotter. Since deflection and unblanking signals are then produced by two sources, provision for mixing is needed. Deflection signals are produced by linear current sources in each module capable of 10-mA output with a maximum swing of +10 V. Thus simple parallel connection of the signal and a load resistor at the oscilloscope input are all that are required to mix the signals. Deflection gain can be adjusted with the value of the resistor to match the particular oscilloscope used. The unblanking pulse (Intensity) undergoes Boolean addition through the same principle. Positive, negative, true, or false unblanking signals are available by suitable jumper setting.

CAMAC COMMAND STRUCTURE

The same command [F(17) A(0)] loads both the x- and the y-register. The first occurrence of the above command after an initialization loads x (or Δx); the second loads y (or Δy) and unblanks the spot or starts vector generation. The process proceeds on this odd-even basis. This somewhat unusual command logic is very efficient in programmed transactions, as a single CAMAC command works for the whole display process. This logic is a must if direct channel data transfer is used.

Sense commands and LAM logic follow the recommendations of TID-25875. Therefore CAMAC Function code 27 senses the Busy state of any operation, completion of an operation sets the Done flag, Function code 8 senses the LAM associated with the Done flag, and Function codes 26/24 enable/disable every LAM.

DIRECT CHANNEL DATA TRANSFER

The DCH (Data Channel) output, with which the PP012, CG018, and VG028 are provided, gives a pulse at the completion of the current display operation to call for the next piece of data. Very fast image construction and refreshing can then be implemented, using, for example, the NC023 NOVA* Crate Controller. One half of a PS016 Preset Scaler is required as a word count register.

*Registered trademark of Data General Corporation, Southboro, Massachusetts.

POINT PLOTTER PP012

The PP012 Point Plotter is intended for point-by-point plots (as shown in Fig. 1) and also as a companion module to the VG028 Vector Generator. Several working modes are available, depending upon the contents of a two-bit control register:

Mode 0 x-y point-by-point display. The register loading mechanism is explained in "CAMAC Command Structure."

Mode 1 y versus x diagrams, coarse x. The load command always puts data into the y-register, increments x by 16 steps, and unblanks the spot. This mode is especially useful to show spectra and histograms with up to 64 classes.

Mode 2 y versus x, fine x. Same as mode 1, but the x scale has the full 1024-point resolution. Any single-value y(x) functional relationship can be represented with full resolution.

Mode 3 y versus an external x. The load command merely sets the y register and displays the point. The x coordinate is supplied by external increment/decrement pulses to the x up-down counter.

Another control register holds intensity information. Four intensity levels are provided, as shown below. Intensity 0 is required if the unblanking signal is produced by another module, such as the Vector Generator.

CAMAC COMMANDS TO THE PP012

LOADING THE CONTROL REGISTERS

F(16) A(0) Write into the intensity register from W1 and W2. Produce a Q.

W2,W1 = 0,0: zero intensity, no unblanking.
W2,W1 = 0,1: 5-μsec unblanking.
W2,W1 = 1,0: 10 μsec unblanking.
W2,W1 = 1,1: 20-μsec unblanking.

F(16) A(1) Write into the mode register from W1 and W2. Produce a Q.

W2,W1 = 0,0: mode 0, x-y plots.
W2,W1 = 0,1: mode 1, y vs x, 64 x values.
W2,W1 = 1,0: mode 2, y vs x, 1024 x values.
W2,W1 = 1,1: mode 3, y vs external x.

F(16) A(2) Write into the L-enable register from W1 and W2. Produce a Q.

W1 enables L from the Display Done flag.
W2 enables L from the Light Pen flag.

DISPLAY COMMANDS

F(17) A(0) Write display information into the x- or the y-register from W1 to W10. Display the point after loading the y-register; then set the Busy flag. Produce a Q.

Mode 0 Data are loaded alternately into the x- and the y-registers, as explained in "CAMAC Command Structure."

Modes 1 and 2 Data enter the y-register; x-register is incremented.

Mode 3 Data enter the y-register; x-register is left unchanged.

With all four modes the data are positive, binary 10-bit numbers.

F(28) A(0) Initialize the register-loading logic. After this command, the first occurrence of Function code 17 with mode 0 loads the x-register.

SENSE COMMANDS

F(8) A(0) Test L associated with the Display Done flag. A Q is produced if the Done flag is set and L is enabled.

F(8) A(1) Test L from the Light Pen flag.

F(10) A(0) Test L associated with the Done flag; clear the Done flag.

F(10) A(1) Test L from the Light Pen flag; clear the Light Pen flag.

F(27) A(0) Test the Display Busy flag. A Q is produced if a display operation is in progress.

READ COMMANDS

F(0) A(0) Read the content of the x-register into R1 to R10. Produce a Q.

F(0) A(1) Read the content of the y-register into R1 to R10. Produce a Q.

Initialize (Z) Clear the x register, the y-register, and the Busy and Done flags. Disable the L's. Initialize the loading logic as Function code 28.

INPUT-OUTPUT SPECIFICATIONS

DEFLECTION SIGNALS

Current source, 10 mA.
Maximum swing, +10 V (load resistor ≤1 kΩ).
Overall accuracy (including linearity, gain stability, and drift) ±1 LSB per day, ±0.05 LSB per °C.
Two parallel-connected LEMO RA 00 C50 connectors per signal.

INTENSITY

Current source per sink, ±10 mA.
Maximum swing, ±6 V.
Output may be positive, negative, true, or false as selected by jumpers.
Two parallel-connected LEMO RA 00 C50 connectors.

INCREMENT/DECREMENT PULSES

Signal as per Table VIII in TID-25875.
Minimum pulse width, 50 nsec.
Maximum rate, 10 MHz.
One LEMO RA 00 C50 connector per signal.

DCH TRIGGER

Signal as per Table VIII in TID-25875.
Pulse width, ~0.5 μsec.

LIGHT PEN

Accepts pulses as per Table VIII in TID-25875.
Minimum width, 50 nsec.
Connector supplies +24 V dc to power the Light Pen amplifier.
LEMO 0 two-wire connector.

POWER REQUIRED

+24 V, 60 mA;
+6 V, 600 mA;
-6 V, 50 mA;
−24 V, 60 mA.

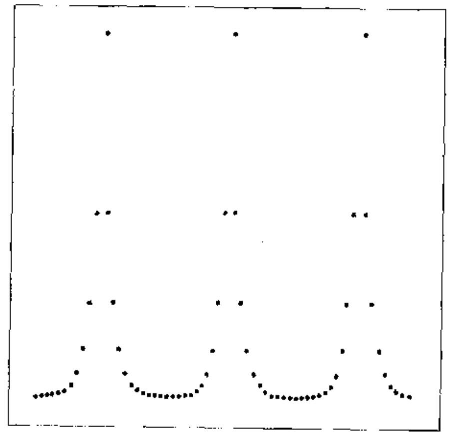


Fig. 1

CHARACTER GENERATOR CG018

The CG018 Character Generator is a self-contained alphanumeric CRT display module. It operates upon simple commands, much like a teleprinter, but has the advantages of a choice of two character sizes, a choice of three intensity levels, and free positioning of the text, both vertically and horizontally, under control of a position register. This is actually a powerful tabulation device.

Like the other members of the family, the Character Generator has provision for a light pen and for direct memory access.

Character Set 63 printing characters: capitals, decimals, punctuation. Space, carriage return, line feed. Characters are formed out of a 7 X 5 point matrix; see Fig. 2.

Text Format 64 lines of 64 characters with size 0. 32 lines of 32 characters with size 1. Size 0 and size 1 can be mixed within the same page.

Code ASCII.

Input-Output Specifications Whenever applicable, same as PP012.

CAMAC COMMANDS TO THE CG018

DISPLAY COMMAND

F(17) A(0) Write into the character register and display the character. Set the Busy flag. Produce a Q. The ASCII character must be presented on W1 to W7.

POSITION AND CONTROL REGISTERS

F(16) A(0) Write into the x-y position register. Produce a Q.

This command is used to set the origin of a text or as a tabulator. Position (0, 0) is the upper left corner. Incrementing x moves the position to the right and incrementing y moves the position down. In the course of writing, the x part of the register is incremented after each character; the y part is incremented by Line Feed. Carriage Return clears the x part. The position register is loaded by two bytes: x from W1 to W6; y from W9 to W14.

F(16) A(1) Write into the size and intensity register. Produce a Q.

W2,W1 = 0,0: 0.5-μsec unblanking per dot.
W2,W1 = 0,1: 0.5-μsec unblanking per dot.
W2,W1 = 1,0: 3-μsec unblanking per dot.
W2,W1 = 1,1: 20-μsec unblanking per dot.
W9 = 0: character size 0.
W9 = 1: character size 1.

F(16) A(2) Write into the L-enable register. Produce a Q.

W1 enables L from the Display Done flag.
W2 enables L from the Light Pen flag.

SENSE COMMANDS

F(8) A(0) Test the L from the Display Done flag. A Q is produced if the Done flag is set and the L is enabled.

F(8) A(1) Test the L from the Light Pen flag.

F(10) A(0) Test the L from the Display Done flag; clear the Done flag.

F(10) A(1) Test the L from the Light Pen flag; clear the Light Pen flag.

F(27) A(0) Test the Display Busy flag. A Q is produced if a character is being generated.

Initialize (Z) Clear the position register; i.e., start the text at the upper left corner of the screen. Clear the flags; disable both L's.

POWER REQUIRED

+24 V, 100 mA;
+ 6 V, 720 mA;
− 6 V, 70 mA;
−24 V, 65 mA.

```
! " # $ % & ' ( ) * + , - . / 0 1 2 3 4 5 6 7 8 9 : ; < = >
? @ A B C D E F G H I J K L M N O P Q R S T U V W X Y Z [ \
] ^ _
```

Fig. 2

VECTOR GENERATOR VG028

The VG028 Vector Generator allows hardware generation of straight-line segments, as shown in Fig. 3. It must be used with the PP012, which provides for the spot position registers and the digital-to-analog converters.

As was stressed earlier, the origin of the vector is stored in the PP012, and the components must be loaded into the VG028.

The data format for the components is a signed binary integer: 10 bits for magnitude (W1 to W10); 1 bit for sign (W11).

A "1" on W16 while the y component is being loaded inhibits the unblanking. This feature is used to jump to a new origin without changing the CAMAC command, a must in direct-channel data transfers. The working principle of the VG028 is purely digital. The x and y rates are produced by binary rate multipliers after some scaling to keep the writing speed roughly constant. The digital principle allows long vectors or endless polygonal lines to be drawn without cumulative errors. The command structure of VG028 is very similar to that of the PP012.

CAMAC COMMANDS TO VG028

DISPLAY COMMANDS

F(17) A(0) Write the vector components alternatively into the Δx or the Δy registers (see "CAMAC Command Structure"). Generate and display the vector after loading Δy; then set Display Busy flag. Produce a Q.

F(28) A(0) Initialize the register loading logic. After this command, the first occurrence of Function code 17 loads the Δy register.

SENSE COMMANDS

F(8) A(0) Test the L from the Display Done flag. A Q is produced if Done is on and L is enabled.

F(10) A(0) Test L from the Done flag; clear the Done flag.

F(27) A(0) Test the Display Busy flag. A Q is produced if a vector is being generated.

CONTROL REGISTER AND L

F(16) A(0) Write into the intensity register from W1 and W2. Produce a Q.

W2,W1 = 0,0
W2,W1 = 0,1
W2,W1 = 1,0
W2,W1 = 1,1 } ~7 msec for a long diagonal vector.

F(26) A(0) Enable L from the Done flag.

F(24) A(0) Disable L from the Done flag.

Initialize (Z) Disable the L, clear the flags, and initialize the register logic as does Function code 28.

For the Input-Output specifications, see PP012 whenever applicable.

POWER REQUIRED

+24 V, 90 mA;
+ 6 V, 750 mA;
− 6 V, 20 mA.

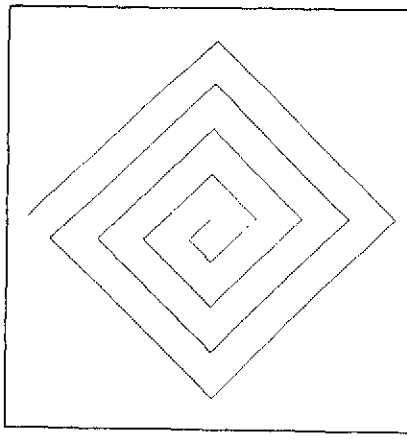


Fig. 3

STORAGE DISPLAY DRIVER DD015

The DD015 is to be used with Tektronix types 601 and 611 storage oscilloscopes or their model 4501 Scan Converter. The DD015 provides all the necessary control signals and timing in response to Dataway commands.

All meaningful associations of the x-y display (PP012), the Character Generator CG018, and the Vector Generator VG028 can be accommodated by the DD015, which also provides a convenient means of connecting these modules to the storage oscilloscope. Deflection and unblanking signals from display modules enter DD015 by coaxial connectors at the front panel and are conducted to the oscilloscope by a multiconductor cable attached at the back of the module that is used for the commands. The cable is 2 m in length and is fitted with the connector required by the Tektronix oscilloscopes. The load resistors for the deflection and unblanking signals are part of the DD015 module and are set to full screen deflection.

COMMAND TIMING

All commands given to the Tektronix storage oscilloscopes take a fairly long time to be executed. For example, the Store Mode is established about 0.1 sec after the command Set Store Mode is released, and the Erase operation lasts for 1/2 sec. During this time no other command or display information can be given. In order to free the programmer — and the computer — from the task of setting up a counting loop to wait for the completion of a command, DD015 incorporates timers and Busy-Done logic for each command. When a command is sent to DD015, a Busy flag is set. As soon as the command is effected or the new mode is established, the logic enters the Done state, clearing the Busy flag and setting the Done flag. The storage oscilloscope is now ready to accept a new command or display information.

The programmer knows about the state of DD015 either in using Function code 27 to test the Busy flag, or in looking for the L-request associated with the Done flag. However, when commands to the oscilloscope are not frequent, it is more convenient to disable the L-requests and test the Busy flags.

CAMAC COMMANDS TO DD015

COMMANDS TO THE OSCILLOSCOPE

F(24) A(0) Clear Store Mode.

F(26) A(0) Set Store Mode.

F(24) A(1) Clear Write Through Mode.

F(26) A(1) Set Write Through Mode.

F(28) A(0) Erase.

F(28) A(1) View.

The commands in the above group produce a Q-response and start the proper timer. The terms "Store," "Write Through," etc., are defined in the Tektronix manuals.

TEST COMMANDS

F(27) A(0) Test Busy flag after set Store Mode and Clear Store Mode.

F(27) A(1) Test Busy flag after set Write Through Mode and clear Write Through Mode.

F(27) A(2) Test Busy flag after command Erase.

F(27) A(3) Test Busy flag after command View.

Function code 27 produces a Q if the flag is on. It can be used whether the corresponding L is masked out or not.

F(8) A(0) Test L produced when Store Mode is established or cleared.

F(8) A(1) Test L produced when Write Through Mode is established or cleared.

F(8) A(2) Test L produced at the end of an Erase operation.

F(8) A(3) Test L produced at the end of a View operation, i.e., when a View command must be given again in order to get a steady display.

F(10) A(0) Test L as F(8) A(0), and clear Done flag.

F(10) A(1) Test L as F(8) A(1), and clear Done flag.

F(10) A(2) Test L as F(8) A(2), and clear Done flag.

F(10) A(3) Test L as F(8) A(3), and clear Done flag.

Function codes 8 and 10 produce a Q-response if the Done flag is on and L is enabled. The L's are controlled by a 4-bit register

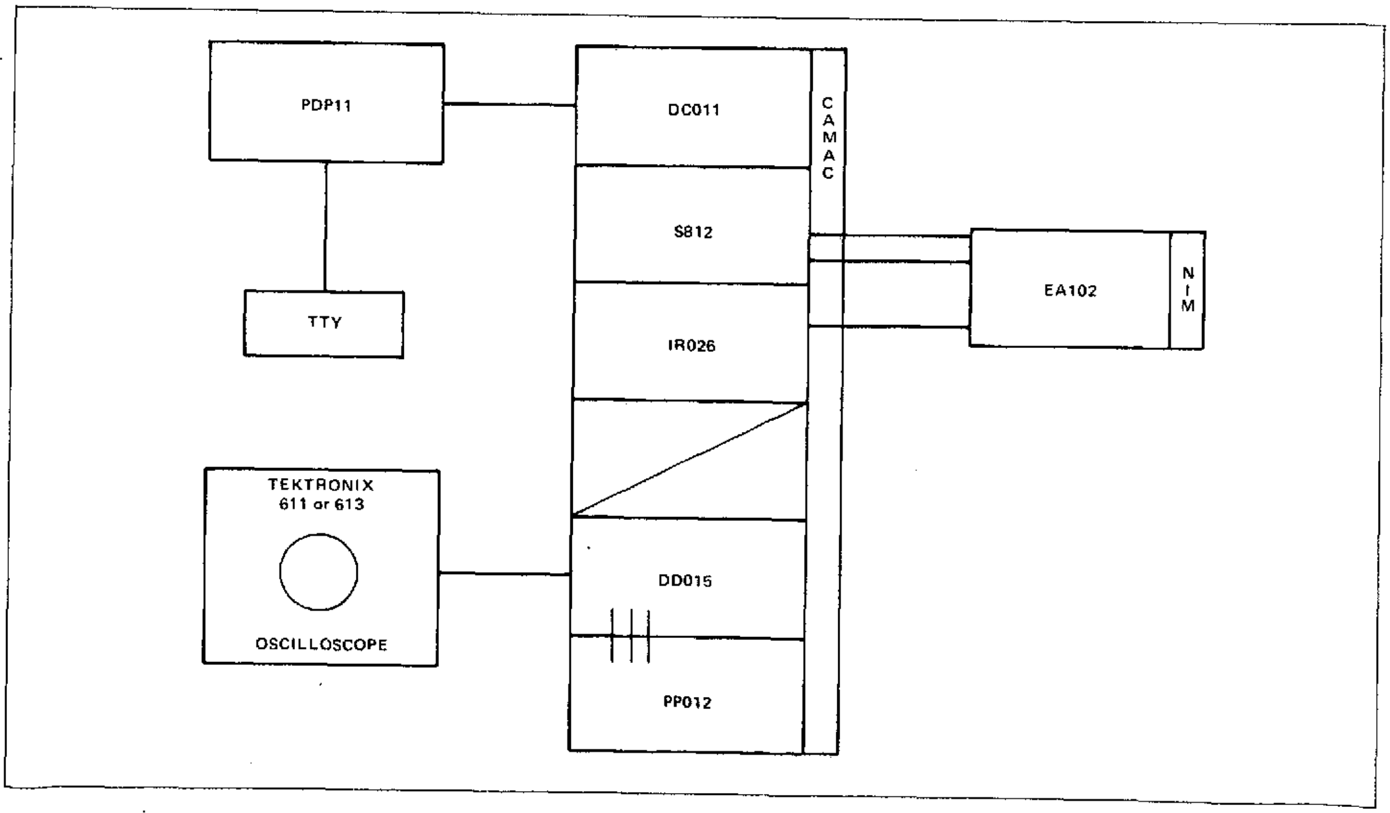
F(16) A(0) Write into the L-enable register from W1 to W4. Produce a Q-response.

W1 enables the L associated with A(0).
W2 enables the L associated with A(1).
W3 enables the L associated with A(2).
W4 enables the L associated with A(3).

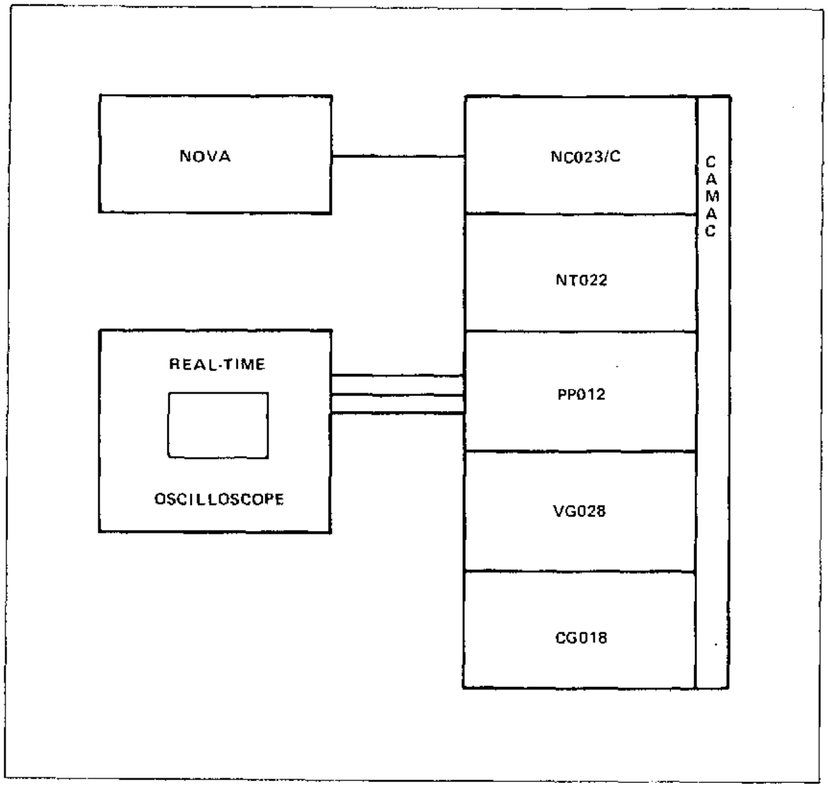
Initialize (Z) Clear Store and Write Through Modes; clear all flags; disable all L's.

POWER REQUIRED

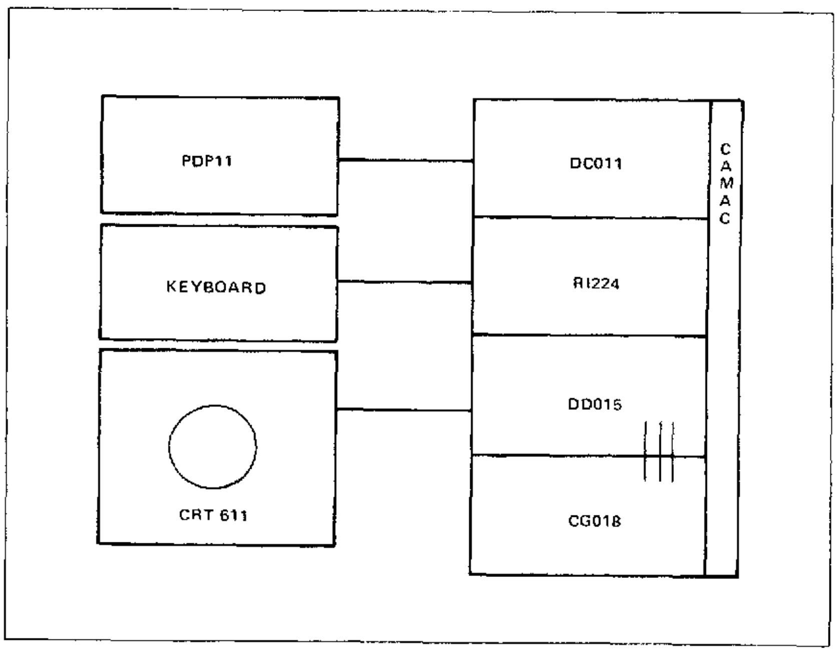
+6 V, 360 mA;
−6 V, 10 mA.



SIMPLE MCA WITH TYPICAL READOUT



FULL COMPUTER GRAPHICS WITH REAL-TIME REFRESHING



COMPUTER TEXT TERMINAL

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EG&G/ORTEC

HIGH ENERGY PHYSICS

Technical Data

CAMAC

DV013 Digital Voltmeter

May 1973

The EG&G/ORTEC DV013 Digital Voltmeter offers two independent integrating digital voltmeters in a single-width CAMAC unit. It is intended for low-cost dc voltage measurement in a hostile electrical environment.

The conversion principle used in the DV013 is known as the "dual ramp" principle: A current proportional to the input voltage is accumulated into a capacitor during a fixed amount of time. The discharge time, at constant current, is a measure of the unknown voltage. Integration time is usually set to offer infinite rejection of line frequency.

The DV013 digitizes bipolar voltages in the range −100 mV to +100 mV without the necessity of switching polarities. It delivers positive or negative 10-bit integers to the Dataway (two's complement). This feature and the differential input allow very convenient high-precision monitoring of slowly varying voltages and compensation type of measurements.

Because of its integrating principle the DV013 cannot compete in speed with other types of converters, but its low cost permits multiconverter arrangement, whereby a set of analog signals may be partitioned with each subset being assigned to a particular scanner and section of the DV013 converter. Thus moderate scan rates can be achieved while retaining the integration principle and without sacrifice of flexibility.

Conversion starts when either a Dataway command or an external "sample command" is given.

SPECIFICATIONS

INPUTS

INPUTS 0 ± 100 mV LEMO 0, 2-wire connectors on front panel.
Range ±100 mV.
Common Mode Rejection 80 dB for maximum ±4 V common mode dc voltage.
Maximum Superimposed ac for Full Rejection 0.3 V rms.
Differential Input Impedance ≥5 MΩ.
Accuracy ±1 LSB after 30 min warmup.
Absolute Maximum Input ±15 V, single or differential.
Integration Time Nominally 20 msec, internally adjusted for infinite rejection between 45 and 65 Hz. (Upon request, integration time as low as 1 msec can be provided.)
Total Conversion Time 20 to 40 msec, input voltage dependent.

EXT SAMPLE LEMO RA 00 C50 connectors on front panel.
Signal TTL compatible: 1 = <0.8 V; 0 = >2 V (see Table VIII TID-25875)..
Absolute Maximum −0.5 V to +4.4 V, internal diode limiting.
Pulse Width Minimum 50 nsec; maximum 20 msec.
Maximum Sample Rate ~20 conversions/sec.

CAMAC CODES

Note: F(ff)·A(a) = Function (ff) with sub-Address (a). Sub-Addresses 0 and 2 are assigned to the upper converter, and sub-Addresses 1 and 3 are assigned to the lower converter.

F(28)·A(0–1) Start conversion. The converter selected by the subaddress starts integrating and

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sets its Busy flag. The end of the conversion process is signaled by the Done flag and eventually by L.

F(0)·A(0–1) Read the content of the converter register selected by the subaddress into R1 to R10 and produce a Q response. Correspondence between the input voltage and the binary data is given in Table 1.

TABLE 1

Differential Input Voltage (mV)	R10	R9	R8	...	R2	R1
>+100*	0	1	1	...	1	1
+100	0	1	1	...	1	1
0	0	0	0	...	0	0
−100	1	0	0	...	0	1
<−100*	1	0	0	...	0	0

*Overrange flag is on.

F(27)·A(0–1) Test the Busy flag, i.e., produce a Q response if the converter selected by the subaddress is busy.

F(8)·A(0–1) Test the L request from the Done flag; Q response is produced if Done flag is on and L is enabled.

F(10)·A(0–1) Test the L request from Done flag as in F(8); then clear the Done flag.

F(8)·A(2–3) Test the L request from the Overrange flag; Q response is produced if the Overrange flag is on and L is enabled.

F(10)·A(2–3) Test the L request from the Overrange flag as in F(8); then clear the Overrange flag.

F(17)·A(0) Write into the L-enable register; produce a Q response: W1 enables L from the Done flag in converter 0. W2 enables L from the Done flag in converter 1. W3 enables L from Overrange flag in converter 0. W4 enables L from Overrange flag in converter 1.

Z Initialize clears all flags and disables all L's.

ELECTRICAL AND MECHANICAL

POWER REQUIRED

+ 6 V, 650 mA;
+24 V, 50 mA;
−24 V, 50 mA;
− 6 V, 15 mA.

PHYSICAL Single-width CAMAC module, sheetmetal covers. Fiberglas circuit board. Meets the electrical and mechanical requirements of EUR 4100e and TID-25875.

EG&G/ORTEC

HIGH ENERGY PHYSICS

Technical Data

CAMAC

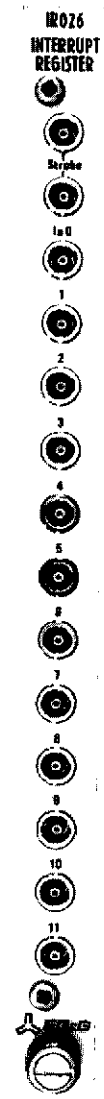
IR026
Interrupt Register

May 1973

The EG&G/ORTEC IR026 Interrupt Register is a 12-bit coincidence and latch circuit for storing and recording the occurrence of NIM signals. The most frequent application of the IR026 is for sampling particle or event patterns in high-energy physics. Inputs to the IR026 are either roughly shaped detector signals or outputs of high-speed decision network. Software algorithms operating upon the bit pattern as read from the Dataway will reconstruct particle position or classify events.

The IR026 is also very useful as a general-purpose L-request module. An L request is produced if at least one latch is set; therefore 12 individual lines can be monitored. A typical application of this concept is the detection of scaler overflows. In this application the strobe is unused.

The automatic testing of NIM-orientated modules or systems requires a means of monitoring the outputs, another application of the IR026.



SPECIFICATIONS

INPUTS

IN 0–11 LEMO RA 00 C50 connectors on front panel.
Impedance ~50Ω.
Maximum 0 Level –200 mV.
Minimum 1 Level 600 mV.
Minimum Pulse Duration 12 nsec.
Typical Required Duration 6 nsec.
Maximum Input +0.6 V, –5 V for proper operation; ±10 V at 25% duty factor without damage.

STROBE LEMO RA 00 C50 connector on front panel. High-impedance bridging input. If Strobe is left open, it will assume the 1 state.
Maximum 0 Level –200 mV.
Minimum 1 Level 600 mV.
Maximum Input +0.6 V, –5 V for proper operation; ±10 V at 25% duty factor without damage.
Minimum Overlap for Coincidence 12 nsec.
Typical Required Overlap 6 nsec.

CAMAC CODES

Note: F(ff)·A(a) = Function (ff) with sub-Address (a).

F(2)·A(0) Read the stored pattern on R1 to R12; clear the register, and produce a Q response.

F(8)·A(0) Test L; a Q response is produced if at least one bit in the register is 1 and if L is enabled.

F(10)·A(0) Test L as in F(8); clear the register; i.e., clear L.

F(26)·no subaddress Set the L-enable flip-flop.

F(24)·no subaddress Reset the L-enable flip-flop; i.e., disable L.

I Inhibits the data input.

C Clears the register.

Z Initialize clears the register and disables L.

ELECTRICAL AND MECHANICAL

POWER REQUIRED
+6 V, 130 mA;
–6 V, 350 mA.

PHYSICAL Single-width CAMAC module, fully enclosed ECL and TTL implementation. Other characteristics meet or exceed TID-25875.

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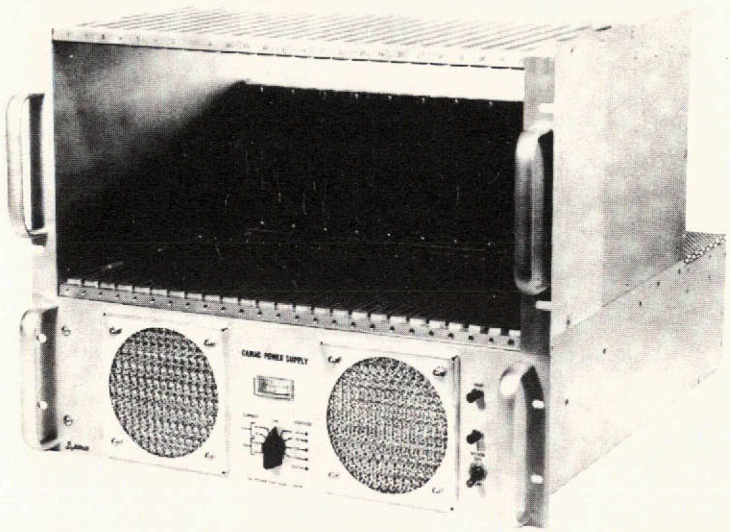
EG&G

Technical Data

CAMAC

MC100
Powered Crate

March 1972



The MC100 consists of a CAMAC crate (MC101) and full-power (300 watts) CAMAC power supply (MC102). The MC100 is constructed in full compliance with the requirements of Specification EUR 4100e and the recommendations for a "Typical CAMAC Power Supply" from the CAMAC Power Supply and Hardware Working Group (9 April 1971). The power supply and crate can be separated for independent operation. The MC100 assembly has the following features:

- Forced-air cooling in the lower unit for both the power supply and the crate.
- The air intake is ducted so that the CAMAC modules and CAMAC power supply have separate sources of fresh air.
- The crate has a rugged, uniform, solid, precision casting for the upper and lower CAMAC module locations.
- Permanent mechanical alignment facilitates easier insertion and removal of a module. The tracks are coated with an anti-galling compound.
- Each slot is numbered for easy location of a particular CAMAC station.
- The power supply features a unique design of a dc converter to reduce the size and, most important, the weight of the transformer core for full dc power. The total CAMAC power supply weighs less than half the weight of a transformer (at 50-60 Hz) alone to supply the same dc power. The MC102 Power Supply is designed for full-powered operation at 300 watts.

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SPECIFICATIONS

POWER

Voltage +6 V, dc; −6 V, dc; 25 A maximum from either line, with a 5 A maximum simultaneous load on the opposite line.

Voltage +24 V, dc; −24 V, dc; 6 A maximum from either line, with a 2 A maximum simultaneous load on the opposite line.

REGULATION

For input voltage and output current:

103	to	128 V, 60 Hz
0	to	25 A, 6 V
0	to	6 A, 24 V

The outputs are:

± 6 V, ± 0.5%
± 24 V, ± 0.2%

STABILITY

After 24 hours warmup, for constant line load and ambient temperature, the output drift is less than ± 0.5% (± 6 V) and ± 0.3% (± 24 V).

NOISE AND RIPPLE

Less than 15 mV peak-to-peak.

AMBIENT TEMPERATURE

The supply will operate from 0°C to 50°C without derating, and the output voltage coefficient is 0.02%/°C over the entire range.

OUTPUT VOLTAGES

Adjustable to ± 2% by easily accessible screwdriver adjustments. Resettable to ± 0.05%.

OUTPUT CONNECTOR

The output connector is AMP Type 200512-3.

PROTECTION

The input line is fused on both sides. The outputs fold back to 3A when current overload is sensed. This will protect the card-edge connector if the short circuit is in one module. When the short circuit is removed, the outputs return to full ratings.

The output voltage is limited to 7.5 volts for the 6-volt supplies and 34 volts for the 24-volt supplies.

The supply is thermally protected with an indicator light on the front panel.

MONITORING

The output voltage and current readings are available on a front-panel meter and at test points.

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HIGH ENERGY PHYSICS

Technical Data

CAMAC

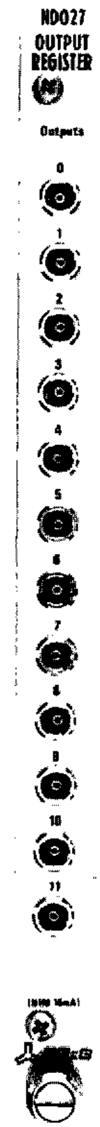
ND027
Output Register (NIM Driver)

May 1973

DESCRIPTION

The EG&G/ORTEC ND027 Output Register (NIM Driver) is a 12-bit transducer – or interface – between the CAMAC Dataway and equipment requiring NIM fast logic levels, and can be operated in the dc or the pulse mode for added flexibility.

The most common application for the ND027 is in a computer-controlled experimental setup. Control bits can be fed into the fast electronic modules for changing signal routing, selecting different decision functions, modifying propagation delays. Also, the pulse mode of the Output Register lends itself to automatic system testing through event simulation.



SPECIFICATIONS

OUTPUTS

OUTPUTS 0–11 LEMO RA 00 C50 connectors; standard NIM outputs; current sink nominally 16 mA. Unused outputs need not be terminated.

CAMAC CODES

Note: F(ff)·A(a) = Function (ff) with sub-Address (a).

F(16)·A(0) Write a 12-bit word into the register from W1 to W12. Produce a Q response.

F(17)·A(0) Write a 12-bit word into the register at S1; clear the register at S2; produce a Q response. This function is used to produce output pulses rather than levels.

Z Initialize clears the register.

ELECTRICAL AND MECHANICAL

POWER REQUIRED

+6 V, 200 mA;
–6 V, 170 mA.

PHYSICAL Single-width CAMAC module, fully closed; TTL implementation. Other characteristics meet or exceed EUR 4100e and TID-25875.

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HIGH ENERGY PHYSICS

Technical Data

CAMAC

PE019 Position Encoder

May 1973

The EG&G/ORTEC PE019 Position Encoder is a dual binary up-down counter intended specifically for digitizing the y-x position with incremental transducers. This module is applicable for many types of automatic and manual measuring instruments:

1. Rotary shaft encoding.
2. Scanning and measuring tables for bubble chamber trajectories (e.g., HPD and IEP devices).
3. Photodensitometer for astronomical spectrometry and other research fields.
4. Mechanical inspection machines.
5. Digital magnetic field pattern plotters.

The up-down counters in the PE019 have a 20-bit capacity, just over 1 million increments. Using a rotary-type transducer with a resolution of 1000 steps per revolution, the module provides unambiguous reading for over 1000 spindle revolutions. A linear transducer with a 0.01-mm resolution is allowed to have a length of over 10 m.

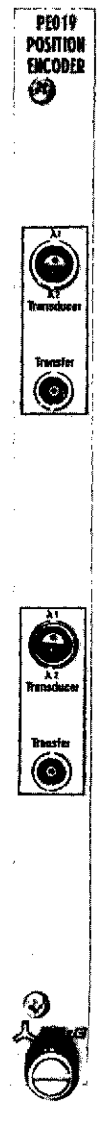
Considerable attention has been given to flexible and efficient interaction between the measuring machine, its operator, the encoder module, and the processor. The following features should appeal to everyone faced with position-digitizing problems:

1. Each up-down counter is fitted with a buffer register. A transfer command – a Dataway command or an externally supplied pulse – "freezes" the value of both coordinates in the buffer registers for subsequent reading by the processor. The counters themselves are neither disturbed nor stopped. Thus coherent multicoordinate recording is an easy matter. The transfer command also sets a flag to inform the processor (by an L request) that a new reading must be performed.

2. Each counter can be preloaded by a Dataway Write Command. Setting the origin of the measurement, even outside the displacement range of the transducer, is the first use of the preloading feature; the large capacity of the counters allows great freedom in this respect. As the module sets an overrange flag when the counter goes over $2^{20} - 1$ or under 0, a suitable preloading of the counter can be used to signal that the moving part of the system has gone beyond some preselected point.

3. All L-request sources can be individually disabled. A transfer command or an overrange flag is a source of L requests. A 4-bit register controls each individual L request. Software-conscious users will appreciate this.

4. The PE019 accepts directly the output of any incremental transducer. Incremental transducers normally deliver two waveforms in quadrature from which count and direction information must be gained. The PE019 has a built-in phase discriminator for direction recognition. A 3-position jumper can be set to produce 1, 2, or 4 counts per period of the transducer waveform. The input conditioner is made from an integrated comparator. Its threshold can be set between –6 V and +6 V by an internal screwdriver adjustment. A true Schmitt characteristic prevents spurious counts encountered from slow rise and/or noisy signals.



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PE019 Position Encoder Technical Data

SPECIFICATIONS

INPUTS

TRANSDUCER Two LEMO type 0, two-wire connectors. Thresholds adjustable between −6 V and +6 V; input impedances, 10 kΩ; Schmitt characteristic with ~300-mV hysteresis; maximum input voltages, ±30 V dc.

TRANSFER Two LEMO RA 00 C50 connectors. TTL-compatible signals (see Table VIII of TID-25875); signals are active on the negative-going transitions; minimum pulse widths, 50 nsec; maximum input voltages, +10 V, −5 V dc.

CAMAC CODES

Note: F(ff)·A(a) = Function (ff) with sub-Address (a).

A(0) and A(2) are assigned to the upper counter in the module; A(1) and A(3) are assigned to the lower counter.

F(28)·A(0−1) Transfer the counter content into its buffer register; set the Transfer flag (this command has the same action as the external Transfer input).

F(0)·A(0−1) Read the buffer register into R1 to R20; produce a Q response (see Note at the end of this section).

F(16)·A(0−1) Preload the counter from W1 to W20; produce a Q response.

F(8)·A(0−1) Test the L request from the Transfer flag, i.e., produce a Q when the Transfer flag is on and L is enabled.

F(10)·A(0−1) Test the L request as in F(8); clear the Transfer flag.

F(8)·A(2−3) Test the L request from the Overrange flag.

F(10)·A(2−3) Test the L as in F(8); clear the Overrange flag.

F(17)·A(0) Write into the L-enable register from W1 to W4; produce a Q response:
W1 enables L from Transfer flag in counter 0.
W2 enables L from Transfer flag in counter 1.
W3 enables L from Overrange flag in counter 0.
W4 enables L from Overrange flag in counter 1.

Z Initialize clears all flags and counters; disables all L's.

C Clears all counters.

Note: The scaler content, as transmitted by F(0), is usually regarded as a positive binary integer in the range 0 to $2^{20}-1$. It might be convenient, however, to preload the counter with 1000...00 at the origin of the coordinate system. Then, complementing the most significant bit by software, the counter content is a two's complement integer in the range -2^{19} to $+2^{19}-1$. The same idea applies if less than 20 bits are used; e.g., if 16 bits are sufficient, the counter is set initially at xxxx1000...00, the range being restricted to -2^{15}, $+2^{15}-1$. Of course, the Overrange flag loses its operational meaning.

ELECTRICAL AND MECHANICAL

POWER REQUIRED
+24 V, 35 mA;
+ 6 V, 930 mA;
− 6 V, 35 mA.

PHYSICAL Single-width CAMAC module with sheetmetal covers on both sides; Fiberglas circuit board with plated-through holes. All TTL and linear integrated circuits. Meets all *electrical and mechanical specifications of* EUR 4100e and TID-25875.

EG&G/ORTEC

HIGH ENERGY PHYSICS

Technical Data

CAMAC

PS016
Preset Scaler

May 1973

DESCRIPTION

The PS016 dual Preset Scaler may be operated as either a preset counter or a programable pulse generator. The mode of operation is selectable by internal jumpers; upon Dataway commands the unit will count and gate or generate a burst of up to $2^{16} - 1$ pulses. As a preset scaler it provides an economical means of timing nuclear experiments; as a pulse generator it may be used for numerical position control for testing scalers or other logic boards or stepping scanners and visual displays. Three typical applications of this module are as follows.

NUMERICAL POSITION CONTROL FOR TESTING STEPPING SCANNERS

A single PS016 can be used for x-y position control or for two independent linear motions. In this application the number of pulses is a signed number; the most significant bit (W16) acts as a sign or direction bit; W1 through W15 give the magnitude of the displacement.

To effect a motion, the programer merely loads the register(s) with the required number of steps. This load command also starts the pulse train. A Busy flag is set and can be tested by F(27). At the end of the pulse train, Busy is cleared and Done is set. The Done flag is an L-request source, but L can be disabled. The Done flag is cleared by F(10) or by loading the register again. The direction of motion is signaled to the motor steering circuits by the Direction output signal, which is generated before the output pulse train is started. The pulse train frequency can be set between 50 and 2000 pulses/sec by internal screwdriver adjustment.

WORD COUNTER IN DCH DATA TRANSFERS

An NC023 NOVA Controller, which is used in CAMAC systems incorporating a NOVA processor, does not contain a word count register, and to make use of the Direct Channel (DCH) facility, the PS016 may be used as a programable pulse gate. A DCH request is initiated upon receipt of a DCH trigger pulse at the NOVA Controller. These trigger pulses are routed through the PS016, whereby they are gated off when the required number of transfers has been counted. The number of transfers is defined by the number loaded into the register of the PS016 and must be a positive integer in the range of 0 to $2^{16} - 1$. An L request is issued to signal the end of the DCH transaction when the contents of the Preset Scaler reach zero.

This example is illustrative of preset count and pulse gate applications of the PS016.

DECIMAL DISPLAY DRIVER

The need often arises to display some critical measurement. With the PS016 driving a simple decimal readout scaler, such as one of the ORTEC 770 Series NIM Scalers, a very convenient decimal display is provided for local or remote operation. This arrangement costs much less than a cathode-ray tube and offers the important advantages of binary-to-decimal conversion by hardware and remote installation with a single coaxial cable.

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SPECIFICATIONS

INPUT

EXT CLOCK Front panel LEMO connector for input pulses to be counted and gated. "1": 0 to 0.8 V, maximum 2 mA out of the module; "0": 2 to 5.5 V (see Table VIII, TID-25875).

OUTPUTS

OUT Front panel LEMO connector for pulse train output. 16 mA current sink. 50 to 2000 Hz by screwdriver adjustment (common to both parts of the module) or ~5 MHz. Pulse width, ~10 μsec at low rate, ~100 nsec at high rate.

RESET OR DIRECTION Produces either a reset pulse before the pulse train or a sign bit. 16 mA current sink, which can be loaded with 50 ohms to provide "fast signal level" (Table IX of TID-25875) or clamped to ground and fitted with a pull-up resistor to drive TTL loads. Reset pulse duration as Dataway S2.

CAMAC CODES

F(17)·A(k) Load the register selected by the sub-Address, k = 0, 1, from W1 to W16. Set Busy flag (i.e., start pulse train or open gate); produce a Q response.

F(27)·A(k) Test Busy flag (produce a Q response during the pulse train or the gate aperture and also during the viewing pause), k = 0, 1.

F(8)·A(k) Test L (produce a Q response if Done flag is set and L is enabled), k = 0, 1.

F(10)·A(k) Test L as in F(8); clear Done flag, k = 0, 1.

F(16)·A(0) Load the L-enable register from W1 and W2, produce a Q response. W1 enables L associated with A(0); W2 enables L associated with A(1).

Z Clears Busy and Done flags; clears L-enable register.

ELECTRICAL AND MECHANICAL

POWER REQUIRED

+6 V, 660 mA;
−6 V, 30 mA.

PHYSICAL Single-width CAMAC module with shield covers, Fiberglas circuit board. Meets the electrical and mechanical requirements of EUR 4100e and TID-25875.

EG&G

CAMAC

RO224

Output Register

Technical Data

March 1972

DESCRIPTION AND OPERATION

The RO224 Output Register is a dual 24-bit output register which enables the central processor via the CAMAC interface to control external apparatus.

The RO224 module is a single width CAMAC module with two (2) 52-pin connectors (Cannon 2DB52S) mounted on the front panel.

The output lines on the front panel connector for each register are:

24 data lines (TTL logic levels with 160 mA/line sink capability).

Status Line The status line indicates that a successful CAMAC data transfer has occurred and this data is available to the user device. The status line may also be termed a "data ready line".

Not Busy Line The Not Busy line indicates to the RO224 whether or not the user device is able to accept the data. When the Not Busy line is high, the RO224 will send the data. This line must drive one TTL load.

Load Pulse The Load Pulse line strobes the data from the RO224 to the user device. This pulse has a user-adjustable width of 1 to 10 µsec and occurs immediately following a CAMAC data transfer if the user device is not busy. If the user device is busy, the pulse occurs as soon as the device becomes not busy.

The Load Pulse and Status lines are reset between CAMAC data transfers.

By using the Status and Not Busy lines, the "handshake" method of data transfer may be utilized.

The RO224 also includes a Status Register which contains the Not Busy and Status line levels from both output registers. By testing this status register, the central processor can defer further transfers until the device has taken the available data and can test whether the device is active.

The CAMAC codes used are:

N·A(0)·F(16)
Overwrite Register 0 Returns Q, X

N·A(1)·F(16)
Overwrite Register 1 Returns Q, X

N·A(3)·F(1)
Read Status Register Returns Q, X

X is decoded and provided as a patch. When the X-line selection is finalized, the modification can easily be made. Z and C reset the control logic lines and data registers to zero.

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CAMAC

Technical Data

RI224 Input Register

March 1972

OPERATION AND FEATURES

The RI224 is a dual 24-bit input register, which accepts TTL levels. It is a single-width CAMAC module with two (2) 52-pin Cannon connectors (2DB52S) on the front panel. The RI224 accepts data from the external devices in three modes:

(1) Accepts new data only after the previous data has been read by CAMAC.

(2) Accepts new data upon command of external device, even if the old data has not been read.

(3) Accepts new data only upon CAMAC command, i.e., the data on the data lines are strobed into the register when the command is received.

The input lines are:

(1) 24 twisted-pair data lines.

(2) 1 twisted-pair data-ready line from the external device to signal to the module that the data lines contain valid data.

(3) 1 twisted-pair mode control line for selecting one of the above modes.

The output line is:

(1) Data acknowledge line:
 (a) Standard - true until data is read out.
 (b) Option - true for a specified time and then false.

By using the data ready and data acknowledge lines, the "handshake" method of data transfer may be utilized.

CAMAC CODES

N·A(0)·F(0) Read Register 0	Returns X, Q
N·A(1)·F(0) Read Register 1	Returns X, Q
N·A(0)·F(2) Read and Clear Register 0	Returns X, Q
N·A(1)·F(2) Read and Clear Register 1	Returns X, Q
N·A(14)·F(1) Read LAM Status Register	Returns X, Q
N·A(0)·F(8) Test LAM	Returns X, Q If LAM True
N·A(13)·F(17) Write MASK Register	Returns X, Q
N·A(13)·F(1) Read MASK Register	Returns X, Q
N·A(0)·F(28) Load Register 0 (Sample)	Returns X, Q
N·A(1)·F(28) Load Register 1 (Sample)	Returns X, Q

NOTES:

(1) Q and X are returned on any VALID N, subaddress, and function code combination except N·A(0)·F(8), "test LAM". Q

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and X are returned only on LAM true in response to N·A(0)·F(8). LAM is the logical "Or" of LAM 0 and LAM 1. LAM is gated off the L line during N true.

(2) Z·S2 resets all control logic and data registers. It also sets the mask register, disabling the LAM from each data register.

(3) I true prevents data from being loaded into the data registers.

AUXILIARY REGISTERS

A LAM status register and a LAM mask register are provided for determining the source of a LAM request and for enabling or disabling each LAM source.

The LAM status register is read with a N·A(14)·F(1) command. During a "read LAM status" command, the R1 line will be true if a LAM request from register 0 is true and R2 line will be true if a LAM request from register 1 is true.

The mask register allows each LAM source to be enabled or disabled by writing a two-bit word with a N·A(13)·F(17) command. A "1" on the W1 line will disable LAM 0 and a "1" on the W2 line will disable LAM 1 when issued with this command. In addition, the mask register contents may be read on bits 1 and 2 of the read (R) lines with a N·A(13)·F(1) command.

EG&G/ORTEC

HIGH ENERGY PHYSICS

Technical Data

CAMAC

RC014
Real Time Clock

May 1973

The EG&G/ORTEC RC014 Real Time Clock is a very versatile preset counter designed to solve almost any timing problem encountered in experimental work. Unlike most real time clocks available from computer manufacturers, the RC014 is directed toward the experimental environment; it works as a link between the physical world and the program.

The key to the flexibility of RC014 is its ability to control and sense every operational step by Dataway commands and/or by front panel signals.

The experimenter and engineer will find the RC014 useful in preset-count and preset-time arrangements. The clock generator mode of the RC014 not only interrupts the processor at regular time intervals but also has pulses and other controls available for the experimental equipment. Still another unusual capability of the module is its function as an elapsed time meter.

Some of the valuable features of the RC014 are as follows:

1. The preset-time range is from 3.8 μsec to 18.2 hr.

2. The preset-count range is from 1 count to 2^{34} counts (more than 17 X 10^9).

3. The resolution is 16 bits.

4. The clock generator rates are from 4 Hz to 1 cycle in 18.2 hr.

5. Readout on the fly allows the elapsed time after a start command to be monitored by Dataway operation while the timing cycle is still in progress.

6. Start and stop commands are by Dataway operations or by external pulses for high precision timing.

7. The start pulse and gate are available at the front panel even if started by a Dataway command.

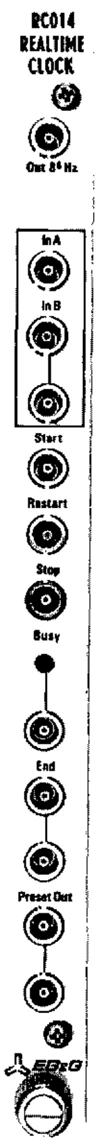
8. A front panel gate input is provided to control the flow of clock pulses into the counter for live-timing application.

9. All front panel signals are NIM-compatible to ease interfacing with fast nuclear instrumentation.

Figure 1 is a functional block diagram of the module. Some Dataway commands are shown, but a complete list appears in the Specifications.

A Dataway command loads the 16-bit counter with the one's complement of the word on the W bus. When the counter goes through zero again, it generates the End output. In front of the preset counter, a frequency divider steps down the input rate, and a control register holds the current step-down ratio. The input circuit is an arrangement that can be found in other scalers: In A is a normal 50Ω input; In B is a high-impedance bridging input, which maintains a "1" (−0.8 V) if left open and a "0" state if terminated in 50Ω. Since both inputs enter an AND-gate, either In A or In B can be used to feed count pulses or gate signals. An ungated mode of operation results when count pulses are fed into In A and In B is left open.

The crystal oscillator is an independent section; in all timing applications of the



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RC014, the dotted line connection to In A must be made on the front panel.

Input of the counter is under control of the Busy flag. An externally supplied Start (or Restart) pulse or a Dataway command sets Busy, which starts the timing or the preset-count operation. The end of the preset-time/count operation clears the Busy flag and sets the Done flag, which might issue an L request. For a more thorough discussion of the "busy-done" philosophy, please refer to the CT021 Data Sheet.

The Start input simply sets the Busy flag; the counter is supposed to be correctly loaded. Restart also turns on Busy but clears the counter, too. In preset-time/count operations, the Start pulse, if not supplied by the physical equipment, can be derived from the counter load command through the dotted line connection to Start.

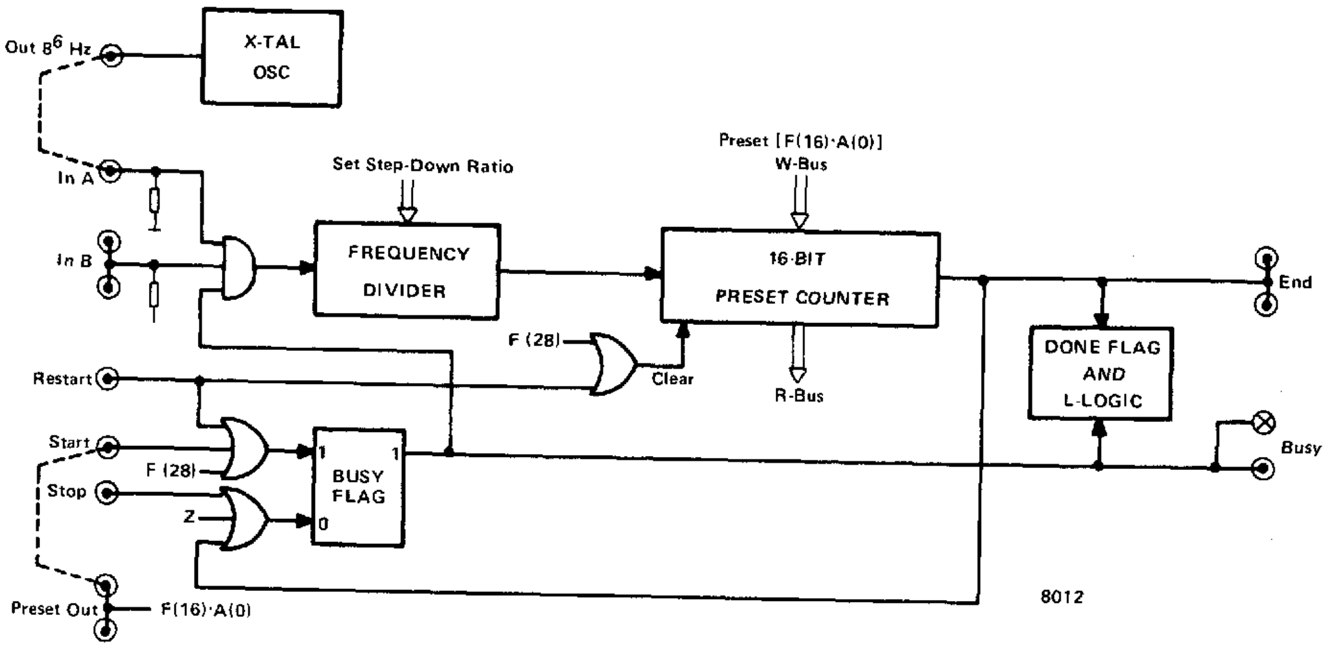


Figure 1

SPECIFICATIONS

All inputs and outputs of the RC014 accept or deliver NIM-compatible levels or pulses. Output drivers sink 16 mA in the 1 state, and inputs accept −800 mV as 1. (For more details refer to Table IX in TID-25875.) All connectors are LEMO RA 00 C50.

INPUTS

IN A Input to the frequency divider; maximum pulse rate, 15 MHz at 50% duty ratio; minimum pulse width, 30 nsec; 50Ω impedance.

IN B Dual high-impedance input to the frequency divider; assumes 1 state when open. Maximum pulse rate, 15 MHz at 50% duty ratio; minimum pulse width, 30 nsec.

START Sets the Busy flag; 50Ω impedance; minimum pulse width, 50 nsec.

RESTART Sets the Busy flag and clears the preset counter; 50Ω impedance; minimum pulse width, 50 nsec.

STOP Clears the Busy flag; 50Ω impedance; minimum pulse width, 50 nsec.

OUTPUTS

OUT 8^6 Hz Crystal oscillator, 262,144 ± 5 Hz, generates an approximately symmetrical square wave. Overall stability; 5 X 10^{-4} (10 to 40°C).

BUSY Busy flag for external use, gives the exact duration of the timing or preset operation; a lamp shows the state of the busy flag.

END Generated whenever the preset counter is clear, especially at the completion of any preset operation or after a Restart pulse; double output (32 mA sink capability).

PRESET OUT Delivers a pulse with a width equal to S2 when the preset counter is loaded [F(16)·A(0)]; double output (32 mA sink capability).

CAMAC CODES

Note: F(ff)·A(a) = Function (ff) with sub-Address (a).

F(16)·A(1) Write into the control register of the frequency divider; clear the frequency divider; produce a Q. Only one bit of the control register is allowed to be nonzero at a time. Step down ratios are as follows:

Control Register* Bit	Step-Down Ratio
W1	2^0 (1)
W2	2^3 (8)
W3	2^6 (64)
W4	2^9 (512)
W5	2^{12} (4096)
W6	2^{15} (32,768)
W7	2^{18} (262,144)

*If the Control Register is 0, the frequency divider will be inhibited.

F(16)·A(0) Write into the preset counter from W1 to W16; produce a Preset Out pulse; clear the Done flag; produce a Q.

W1–W16 A binary integer: the number of time increments or pulses to be counted (multiplied by the step down ratio). After this command, the counting register holds the one's complement of this integer.

F(28)·A(0) Clear the preset counter; set the Busy flag; i.e., start counting. Clear the Done flag.

F(0)·A(0) Read the preset counter into R1 to R16; produce a Q.

READ PROCESS Stops the counter for a fraction of the Dataway operation (from t_0 to t_6; refer to Fig. 9 of TID-25875) in order to avoid ambiguous reading. A single pulse occurring during this interval is restored to the counter at S2. Thus readout on the fly is possible without loss if the reciprocal of the pulse rate (after the divider) is larger than the interval $t_0 - t_6$. At higher rates the losses are generally negligible.

F(27)·A(0) Test the Busy flag; *i.e., produce* Q = 1 if Busy is on.

F(8)·A(0) Test L produced by the Done flag; i.e., Q = 1 if Done is set and L is enabled.

F(10)·A(0) Test L as in F(8); clear the Done flag.

F(26)·A(0) Enable L.

F(24)·A(1) Disable L.

Z Initialize clears Busy and Done flags; clears the preset counter and the frequency divider; disables L.

ELECTRICAL AND MECHANICAL

POWER REQUIRED

+6 V, 640 mA;
−6 V, 90 mA.

PHYSICAL Single-width CAMAC module with sheetmetal covers, Fiberglas circuit board and all TTL integrated circuits, meets all electrical and mechanical requirements of EUR 4100e and TID-25875.

APPLICATIONS

TIMER

After Start, Busy is on and available as a gate to external equipment (see Fig. 2). The completion of the timing operation is signaled to the program by an L request and to the experimenter by End and Busy. The Start command is supplied by either a pulse or a programmed command. In the latter case a connection Preset Out–Start must be established. Figure 3 shows the effect of a Stop command during the timing operation.

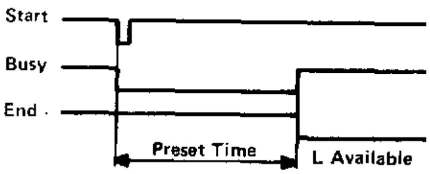


Figure 2

The output of the time base oscillator, Out 8^6 Hz, should be connected to In A. When a pulse train other than the time base oscillator is supplied to In A (or In B), the timer becomes a preset counter.

CLOCK GENERATOR

Making a connection from Out 8^6 Hz to In A and feeding End back to Restart provide a free-running clock generator. Pulses of about 100-nsec duration are available at the End output. The clock rate is dependent only upon the step-down ratio:

Step-Down Ratio	Clock Period
2^0	1/4 s
2^3	2 s
2^6	16 s
2^9	128 s
2^{12}	1024 s
2^{15}	8192 s
2^{18}	65536 s

At the end of every period, an L request is issued which may be used to interrupt the current program in the processor. Provision must be made to service the interrupt before the next clock period.

ELAPSED TIME METER AND DAYTIME CLOCK

The readout on the fly and the front panel commands allow many useful arrangements. The elapsed time meter measures the time between an initial event (t_0) and a second event (t_1). The instants t_0 and t_1 are sometimes given by pulses (t_0 into Restart and t_1 into Stop) or are defined by the program, say, in response to a certain interrupt routine. The program then uses F(28) at t_0 and reads the counter on the fly at t_1 by function 0. High-resolution timing, however, is possible only with pulse commands. Once started at t_0, the current counter content can be transferred to the processor as often as desired. A hardware daytime clock results.

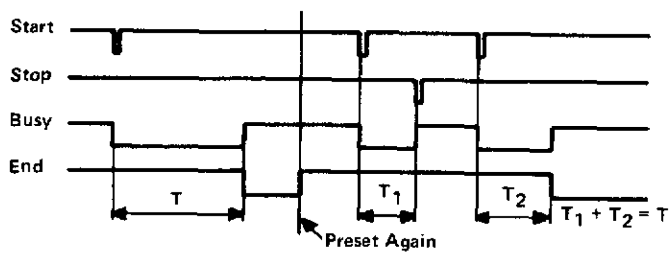


Figure 3

EG&G

CAMAC

TC024
Terminator

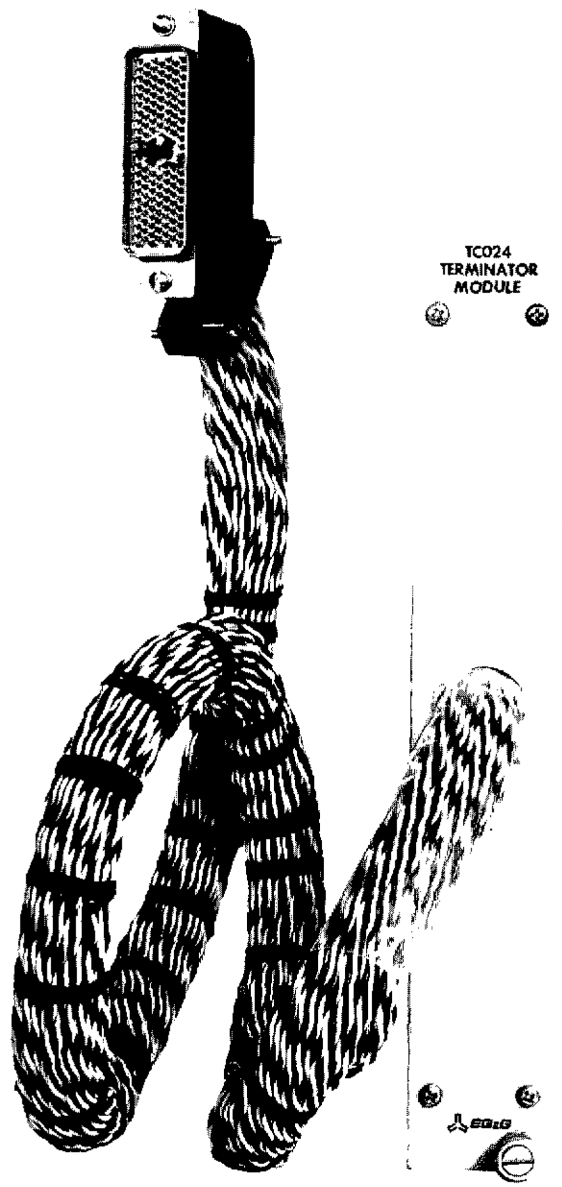
Technical Data

March 1972

The TC024 is a double-width CAMAC module that provides Branch Highway termination in conformance with the requirements of CAMAC Specification EUR 4600e. Connection to the Branch Highway is made via a 66-twisted-pair cable and a Hughes connector from the front panel. No additional external cable is required. Connection is made via the Data Highway connector to +6V and ground.

The characteristic impedance is approximately 90Ω, with maximum "1" current limited to 45 mA. Maximum voltage is approximately 4.1V.

The TC024 has exceptionally uniform characteristics across all 66 twisted-pair signal lines because of its defined connection to the Branch Highway, single mated connector pair, and fixed cable length.



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CRYSTAL CONTROLLED CLOCK GENERATOR, MODEL CG

The Joerger Enterprises Model CG is a 10MHZ Crystal Controlled Clock Generator. It conforms to Camac specifications EUR4100e (TID25875), 1972. The unit provides 8 clock outputs simultaneously. These are decade steps of either the internal 10MHZ crystal oscillator or it can divide down an external input, of up to 50MHZ, in decade steps.

An option is offered that will allow the generation of an additional output which can be remotely programmed from the dataway. A register is loaded with data from Write line W1, 2, 3 to determine which frequency will be gated to this output connector.

MODEL CG SPECIFICATIONS

FREQUENCY SOURCE SWITCH — This selects the frequency to be counted down. Either the internal 10MHZ oscillator or an external input.

EXTERNAL FREQUENCY INPUT

Amplitude	+3 volts
Frequency	50MHZ maximum

OUTPUTS

All eight outputs are supplied simultaneously on individual Lemo connectors. When using the internal oscillator the outputs are:

10MHZ, 1MHZ, 100KHZ, 10KHZ, 1KHZ, 100HZ, 10HZ, 1HZ

Stability $\pm$.01%

When using an external frequency input "F" the outputs are:

F, $Fx10^{-1}$, $Fx10^{-2}$, $Fx10^{-3}$, $Fx10^{-4}$, $Fx10^{-5}$, $Fx10^{-6}$, $Fx10^{-7}$

Signal Levels: The output is capable of driving either TTL inputs or fast NIM, 50 ohm inputs.

Amplitude into TTL inputs	3 volts minimum
Amplitude into 50 ohms	-1 volt minimum

PROGRAMMED CONTROL FREQUENCY OUTPUT OPTION

This option provides an additional output clock signal. This signal can be any of the eight output signals supplied and is selected from the dataway.

CAMAC COMMANDS

N·F16·A0	Loads the 3 bit register at S1 with data from the Write lines 1-3. Generates a Q and X response.
i.e. Load 000	Frequency out will be 10MHZ or the external frequency if in External mode.
Load 111	Frequency out will be 1HZ or Fx10^{-7} if in External mode.
TEMPERATURE RANGE	0^{o} to 60^{o} C
POWER REQUIREMENTS	$\pm$6 volts 8 watts maximum
SIZE	#1 Camac module with sliding metal shields.

1172

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CAMAC Branch Terminator
Model BT-01

GENERAL DESCRIPTION

The model BT-01 terminates the standard branch highway described in EUR 4600 (1972). All the circuitry is mounted inside the case of a Hughes 132 pin connector. The terminator requires +6 volts and ground. A two wire cable is provided to connect to a power source. The terminator does not require any slot space in the crate or the branch highway jumper cable.

September 1973

KineticSystems

CAMAC Differential Output Register
Model 3030

GENERAL DESCRIPTION

The model 3030 is a single width module for transmitting 16 bits of data on balanced lines. Control is provided for either synchronous or asynchronous transmissions. All external connections are made via a 52 pin "2D" connector at the rear of the module.

TIMING

For asynchronous transfers, a hand-shaking technique is used for timing. When the output register is written (F16·A0), the module drops a flag indicating that the data is ready. When the receiver recognizes this and receives the data, it drops its flag. That causes the 3030 to assert its flag (a LAM) to signal the computer for the next word.

For synchronous transfers a pulse is generated on a separate output each time the output register is written.

INTERFACE

The line drivers are the National type DM8831A or equivalent. The input for the receiver flag is differential and compatible with the DM8831A.

The model 3030 is a companion to the model 3430 Differential Input Module.

FRONT PANEL

A jack-screw is provided, which functions both for insertion and extraction of the module. The status indicators are:

N light - flashes whenever this module is addressed.
LE light - ON whenever the LAM is enabled.
L light - ON whenever the LAM is pending.

COMMAND	ACTION
F(1)·A(15)	Gates the module identifying number (3030) onto the Dataway.
F(8)·A(0)	Returns the Q if LAM is set.
F(10)·A(0)	Clears LAM.
F(16)·A(0)·S1	Writes the output register from the Dataway, clears the LAM, and generates a strobe pulse at S2.
F(24)·A(13)·S2	Disables LAM.
F(26)·A(13)·S2	Enables LAM.
Z·S2	Clears LAM and disables the LAM.

August 1973

KineticSystems

CAMAC Dual 24 Bit Output Register
Model 3072

GENERAL DESCRIPTION

The Model 3072 provides 2 - 24 bit registers that can be written from the dataway. These registers are connected to output circuits which can drive relays, lamps, solenoids, or any similar devices.

OUTPUT

Each bit has an output circuit which consists of an open collector transistor with a grounded emitter. The transistor is "on" whenever there is a 1 in the corresponding bit of the data register. Each output can sink 250mA with a maximum open circuit voltage of 30 volts. Inductive loads should be diode suppressed at the load to remain within the voltage rating. Internal diode suppression clamped to +24 volts is available on special order. The outputs appear at the rear of the module on a 52 pin "2D" connector above the dataway.

FRONT PANEL

A jack-screw is provided, which functions both for insertion and extraction of the module. There is an "N" light which flashes whenever this module is addressed.

COMMAND	ACTION
F(1)•A(15)	Gates the module identifying number onto the Dataway. 3072 = 6000_8
F(16)•A(0)•S1	Writes Data Register 1 from the Dataway.
F(16)•A(1)•S1	Writes Data Register 2 from the Dataway.
C•S2	Clears the 2 - 24 bit registers.
Z•S2	Clears the 2 - 24 bit registers.

The module returns Q = 1 and X = 1 for all valid commands and 0 otherwise. The registers are cleared during power-up.

August 1973

KineticSystems

CAMAC 12-bit Output Register with Isolated Transistors
Model 3082

GENERAL DESCRIPTION

The model 3082 is a single-width module that contains a 12-bit register for holding binary output data. Twelve output transistors, driven by optical isolators, are provided. The states of these outputs are determined by the bits in the register. The outputs may be turned ON and OFF singly or in combination by a versatile set of CAMAC commands, making the module particularly useful for control applications. The register can be written, cleared, set, selectively cleared, selectively set, and read. Individual bits may be set or cleared via command and sub-address.

The 3082 fully decodes all Functions and Sub-addresses and returns Q for valid commands.

INTERRUPT CAPABILITY

A LAM flip flop is provided which, when enabled, is set by a negative-going transition of an external input or by command. The LAM is cleared by direct command or by any command that affects the contents of the register. Sequences of programmed outputs can thus respond to internal or external control.

OUTPUTS

All external connections are made via the 36-pin edge connector located above the dataway connector. The optical isolators provide effective ground isolation. The open-collector outputs are rated at 30 volts and 100 milliamperes. Supply voltage for the phototransistors in the optical isolator must be provided from the driven circuit. Because of pin limitations the outputs are in six groups of two transistors each.

The optical isolator-output transistor combinations provide typical turn-on times of 10 microseconds and turn-off times of 200 microseconds. Thus, data transfer rates greater than 5KHz are possible. The output "ON" voltage drop is less than 0.3 volts at 100 milliamperes and less than 0.1 volts at 10-milliampere load. A high speed version of the Model 3082 is available on special order. Typical turn-on times of 2 microseconds and turn-off times of 5 microseconds are provided by high speed module.

FRONT PANEL

A jack-screw is provided which functions both in insertion and in extraction of the module. The status indications on the front panel are:

N light - flashes whenever this module is addressed
LE light - ON whenever LAM's are enabled
L light - ON whenever a LAM is pending.

CAMAC 8 Channel, 10-Bit Digital to Analog Converter
Model 3110

GENERAL DESCRIPTION

The model 3110 is a single width module for generating 8 computer controlled analog voltages. The output is 0 to 10 volts at 20 mA maximum. A 10-bit register is provided for each channel that can be read and written using the dataway. The accuracy of the output is better than ±.05% of full scale and the response time is better than 1 msec. The outputs appear at the rear of the module on a 36 pin printed circuit edge connector above the dataway connector.

FRONT PANEL

A jack-screw is provided, which functions both for insertion and extraction of the module. There is an "N" light which flashes whenever this module is addressed.

COMMAND	ACTION
F(0)•A(X)	Gates Register X into Dataway.
F(1)•A(15)	Gates the module identifying number (3110) onto Dataway.
F(16)•A(X)•S1	Writes Register X from Dataway bits W1 to W10.

X can range from 0 to 7.

The module returns Q=1 and X=1 for all valid commands and 0 otherwise.

1972

KineticSystems

CAMAC Stepping Motor Controller
Model 3361

GENERAL DESCRIPTION

The Model 3361 is a double width CAMAC module that contains the controls and driving circuits for a typical stepping motor. Writing a 16-bit sign and magnitude word into a countdown register initiates a process that counts the register down to zero while generating a new output phase at each count. Four open collector transistor switches are provided which switch in the appropriate phase sequence for either stepping clockwise or stepping counterclockwise depending on the sign bit. The clock rate accelerates linearly from zero to a present clock rate and back to zero as the final value is approached. The acceleration time can be adjusted from 20 milliseconds to 2 seconds and the maximum clock frequency can be adjusted from 50 pps to 4,000 pps.

The countdown is halted at a count of zero or upon a contact closure at one of two external inputs. The sign bit determines which of the external inputs is able to inhibit the counting process and an attempt to restart the counting by writing a signed number while the related input is grounded will fail. The number will not be written and No-Q will be returned. Typically, the two external inputs are a clockwise limit switch and a counterclockwise limit switch. The countdown registers are both readable and writeable.

REMOTE CONTROL

Two inputs are provided, one for clockwise and one for counterclockwise, to allow an external device to step the motor independent of the computer. These inputs are TTL levels and increment on the falling edge.

POSITION MONITORING

There are two pulse outputs for monitoring positions of devices, one for clockwise and one for counterclockwise. A pulse is produced on the appropriate output whenever the motor is stepped either from the computer or from the remote control. These outputs are suitable for connecting to one channel of the Model 3640, Quad Presettable Up-Down Counter. After this counter is initialized, it will then keep track of the position of the device controlled by the stepping motor controller.

OUTPUT CIRCUIT

The output circuit consists of four open collector transistor switches with emitters tied in common. Each collector has a clamping diode tied to a common bus which should be connected to the positive terminal of the motor power supply. The motor power supply and current limiting resistors are external to the module. The output switch is isolated from the module ground. The motor power supply should not exceed 28V. The switch current should not exceed 6 amperes. An open collector control switch is provided which can be controlled by dataway command. It can switch 24V at 100mA.

INTERRUPT CAPABILITY

A LAM source bistable is cleared by a write or clear command and set by the count reaching zero or by the count stopping due to an external inhibit. The LAM may be tested or the 3-bit status register which contains the LAM source information may be read. The LAM may be enabled and disabled. The LAM sources are count register equals zero, clockwise limit, and counterclockwise limit.

FRONT PANEL

A jack-screw is provided which functions both in insertion and in extraction of the module. The status indications on the front panel are:

N light	-	Flashes whenever this module is addressed
LE light	-	ON whenever LAM is enabled
CW light	-	ON whenever CW limit is present
CCW light	-	ON whenever CCW limit is present
Control light	-	ON whenever the control bit is set
LS light	-	ON whenever LAM source is set

COMMAND	ACTION
F(0)·A(0)	Gates sign bit and 15-bit countdown register onto Dataway.
F(1)·A(12)	Gates 3-bit status register onto Dataway.
F(1)·A(15)	Gates module identifying number onto Dataway.
F(8)·A(15)	Returns Q if LAM source is true.
F(10)·A(0)·S1	Clears LAM status bit.
F(16)·A(0)·S1	Latches sign bit, writes data into 15-bit countdown register, and initiates countdown at S2.
F(24)·A(0)·S1	Disables LAM status bit.
F(25)·A(0)·S1	Stops motor.
F(26)·A(0)·S1	Enables LAM status bit.
F(28)·A(0)·S1	Clears control bit.
F(30)·A(0)·S1	Sets control bit.
Z·S2	Clears LAM status bit, disables LAM, and clears control bit.

The module returns Q = 1 and X = 1 for all valid commands except F(8)·A(15) where Q depends upon the results of the test. The module returns Q = 0 and X = 0 for all invalid commands.

KineticSystems

CAMAC 24-bit Input Gate
Model 3420

GENERAL DESCRIPTION

The model 3420 is a single-width module that provides means for gating 24 bits of external data onto the Dataway. The data may be either low-true or high-true, selectable by a boardmounted switch. For applications where the input data is multiplexed from a number of sources, the module provides a 6-bit output for selecting one of up to 64 channels. Three output strobes, each 2 microseconds in duration, are provded for use as commands to the external devices. The strobes may each be selected by strap to be high-true or low-true. One strobe, produced by the READ command at S2, is useful as a digitize command to analog-to-digital converters.

INTERRUPT CAPABILITY

A LAM source bistable is provided which is cleared by READ command and set by a negative-going edge of an external low-true data-ready signal. An output from the LAM source provides external devices with means for determining when the data has been read.

INPUTS

All external connections are made via the 36-pin edge connector located above the dataway connector. The logic threshold is approximately 1. 7 volts, and the acceptable input voltage range is ± 10 volts. The inputs are each diode-clamped to Ground and +5 volts through series 470-ohm resistors. The inputs are pulled up by 2200-ohm resistors when in low-true mode and are pulled down when the data is high true.

FRONT PANEL

A Jack-screw is provided when functions both in insertion and in extraction of the module. The status indications on the front panel are:

N light - flashes whenever this module is addressed

LE light - ON whenever LAM is enabled

L light - ON whenever a LAM is pending.

August, 1972

COMMAND	ACTION
F(0) · A(X)[1]	Gates external "group one" data onto Dataway and produces output strobe at S2.
F(1) · A(X)	Gates external "group two" data onto Dataway and produces output strobe at S2.
F(2) · A(X)	Gates external "group three" data onto Dataway and produces output strobe at S2.
F(3) · A(X)	Gates external "group four" data onto Dataway and produces output strobe at S2.
F(6) · A(0)	Gates module identifying number onto Dataway.
F(8) · A(0)	Returns Q if LAM is set.
F(10) · A(0) · S1	Clears LAM.
F(14) · A(0) · S1	Sets LAM.
F(24) · A(0) · S1	Prevents setting of the LAM flip flop.
F(25) · A(0) · S1	Produces "Execute" output strobe.
F(26) · A(0) · S1	Allows setting of the LAM flip flop.
F(27) · A(0) · S1	Produes "Test Status" output strobe.
C · S2	Clears LAM
Z · S2	Clears LAM and prevents LAM from being set.[2]

NOTES

1. The Sub-address (X) may range from 0 through 15.
2. May be changed via strapping option to allow LAM to be set.

KineticSystems

CAMAC Differential Input with Addressing
Model 3430

GENERAL DESCRIPTION

The Model 3430 is a single width module for receiving 16 bits of data on balanced lines from up to 128 sources. A 7-bit address is transmitted on balanced lines. Control is provided for either synchronous or asynchronous transmissions. All external connections are made via a 52 pin "2D" connector at the rear of the module.

ADDRESSING

There is a 7 bit address register that can be read, written, and cleared by command. It is incremented at S2 on every read. If the address exceeds a switch selected final address, then Q = 0 on a read.

TIMING

For asynchronous transfers, a hand-shaking technique is used for timing. When the addressed device has its data ready, it drops a flag. The module latches the data and asserts a flag (module busy). The external device then asserts its flag. When the module is read (F0), it increments the address and drops its flag (indicating that it's ready for next word). The new addressed device can now begin its cycle.

For synchronous transfers, the 3430 functions as an input gate. After its address becomes true, the remote data source must connect its data to the bus before the next read.

The module has one LAM source, the module busy flag. This flag can be enabled, disabled, tested, and cleared by dataway command. It is cleared on a read at S2.

RESET

The module has a reset output which is a 1 μsec pulse generated in response to a dataway command. This can be used to initialize remote date sources.

INTERFACE

The differential line receivers are compatible with National type DM8831 balanced drivers. These drivers are of the Tri-state logic family, and can be multiplexed onto a data bus.

FRONT PANEL

A jack-screw is provided, which functions both for insertion and extraction of the module. The status indications are:

- N light - flashes whenever this module is addressed.
- LE light - ON whenever the LAM is enabled.
- L light - ON whenever the LAM is pending.

COMMAND	ACTION
F(0)·A(0)	Gates Data Register onto Dataway. Increments Address Register at S2.
F(1)·A(0)	Gates Address Register onto Dataway.
F(1)·A(15)	Gates the module identifying number onto the Dataway. $3430 = 6546_8$
F(8)·A(0)	Returns Q if LAM is set and enabled.
F(9)·A(0)·S1	Clears Address Register and LAM.
F(10)·A(0)·S1	Clears LAM.
F(17)·A(0)·S1	Writes Address Register from Dataway.
F(24)·A(13)·S2	Disables LAM.
F(25)·A(0)·S2	Generates Reset.
F(26)·A(13)·S2	Enables LAM.
(Z or C)·S2	Clears Address Register and LAM and disables LAM.

This module returns X = 1 for all valid commands and Q = 1 for all valid commands except F(8)·A(0) where the Q response depends upon the results of the test.

KineticSystems

CAMAC 24-bit Isolated Input Gate
Model 3471

GENERAL DESCRIPTION

The Model 3471 is a single width CAMAC module that provides twenty-four (24) individually isolated contact sense circuits. The sense circuit detects the presence or absence of voltage at its terminals and is particularly suitable for sensing such remote process contact closures as limit switches, machine tool relay contacts, pressure switches, manual switches and mercury-wetted contacts. Four voltage options are available: 12 VDC, 24 VDC, 48 VDC and 120 VAC.

INPUT CIRCUIT

Input isolation is achieved by the use of LED/phototransistor optical isolators. Each circuit is a floating two-wire circuit with common-mode voltage isolation greater than 500 volts. All circuits in one module have like input voltage ratings, and the switching threshold is approximately one-half the rated input voltage. The input circuits each draw more than 5 but less than 10 milliamperes.

The logic convention is such that a contact closure (input voltage present) is interpreted as a logical 1.

SIGNAL CONDITIONING

Each input is conditioned by filtering after the optical isolator. The filter time constant is normally 100 milliseconds. Optional time constants of 10, 50 and 200 milliseconds are available.

INPUT CONNECTOR

The input signal connector is a 52-pin double density type 2DB52P. This connector is mounted on the module front panel. Other connector arrangements, including rear mounting can be made available on special order.

FRONT PANEL

A jack-screw is provided which functions both in insertion and in extraction of the module. Status indications on the front panel are an N-light which flashes when the module is addressed and 24 LED's that monitor the input signals.

COMMAND	ACTION
F(0)•A(0)	Gates input data onto the Dataway.
F(1)•A(15)	Gates module identifying number onto the Dataway. The high byte (bits 17-24) contains bits representing the input voltage option and the time constant option.

The module returns Q = 1 and X = 1 for all valid commands and 0 otherwise.

August 1973

KineticSystems

CAMAC Timing Module
Model 3655

GENERAL DESCRIPTION

The Model 3655 is a single-width CAMAC module containing a 16-bit counter and eight 16-bit set point registers that are compared with the counter. The comparisons produce output pulses on the front panel (TTL, positive true, 200nSec duration), and any of the comparisons may be used to stop or reset the counter. The comparisons also produce LAM sources, which can be individually enabled to produce an L signal.

The module provides its own crystal clock, and the input frequency to the counter can be any decade from 1Hz to 1MHz. The input to the counter can also be from an external source, and the counter can be cleared by an external signal or contact closure. Two of the comparisons can set and clear the dataway inhibit.

Numbers stored in the eight (or less if fewer pulses are required) registers must be in increasing numerical order for proper timing of output pulses.

CONTROL REGISTER

Two control registers are provided. The bit assignments in the registers are:

Cycle Control

Bit	Function
1, 2, 3	N, where the input frequency to the counter is $f_{in} = 10^N$Hz. (N = 7 selects the external input.)
4, 5, 6	Set point number to stop or recycle.
7	1 = recycle, 0 = stop

[written by F(17)·A(0)]

INHIBIT Control

Bit	Function
1, 2, 3	Set point number to set the dataway inhibit, I.
4, 5, 6	Set point number to clear the dataway inhibit, I.

[written by F(17)·A(9)]

FRONT PANEL

A jack-screw is provided which functions both in insertion and in extraction of the module.

There are ten LEMO-00 connectors: eight for the outputs, one for an external start/clear signal, and one for an external clock signal. There are lights beside each pulse output connector to indicate which channel is armed to output a pulse. An L light is on whenever an L is pending, and an N light flashes whenever the module is addressed. An IS light is on whenever the Inhibit line is being asserted by this module.

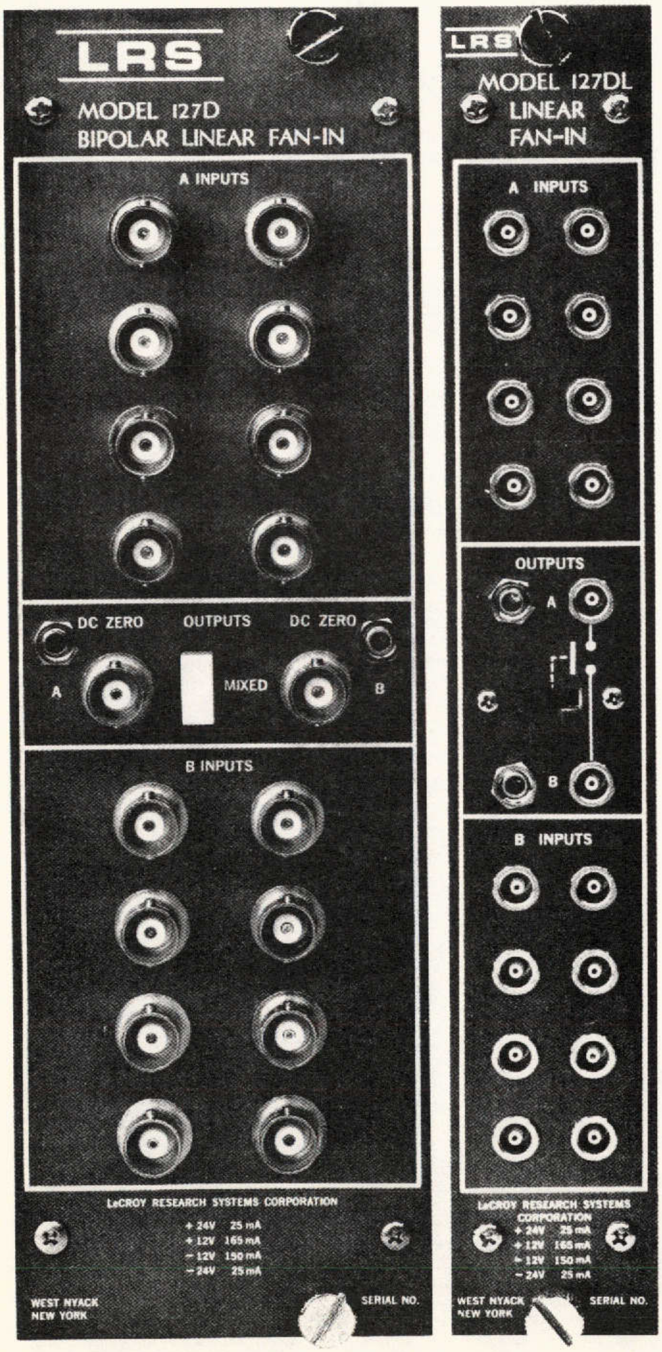
COMMAND	ACTION
F(0)•A(i)*	Gates the value of the set point i onto the dataway.
F(1)•A(12)	Gates the LAM source register onto the dataway.
F(1)•A(15)	Gates the module characteristic (7107_8) onto the dataway.
F(8)•A(15)	Returns Q = 1 if the L is set and Q = 0 if the L is clear.
F(9)•A(8)•S1	Clears and enables the counter and clears the LAM source register.
F(11)•A(12)•S1	Clears the LAM source register.
F(16)•A(i)•S1	Writes the value of set point i from the dataway.
F(17)•A(0)•S1	Writes the cycle-control register from the dataway.
F(17)•A(9)•S1	Writes the inhibit-control register from the dataway.
F(17)•A(13)•S1	Writes the LAM mask register from the dataway.
F(24)•A(9)•S1	Disables I.
F(25)•A(0)•S1	Starts cycle (clears and enables counter).
F(26)•A(9)•S1	Enables I.
Z•S2	Disables the counter and clears the LAM source register.
C•S2	Clears the LAM source register.

*i can range from 0 to 7.

Q and X are returned for all valid commands, except for F(8)•A(15) wherein the status of Q depends upon the status of the L signal.

TECHNICAL DATA

LRS



NIM Model 127D/127DL

Dual Bipolar Linear Fan-In

The LRS Model 127D is a fast, versatile bipolar linear fan-in featuring unity gain, non-inverting operation, direct-coupled circuit design and freedom from duty cycle limitations and rate effects. The instrument is based on the proven design of the popular LRS Model 127C, offering improved overload characteristics, output waveshape fidelity, and long-term DC stability. The Model 127D operates as either a dual 8-fold linear fan-in or as a single 16-fold linear fan-in. With rise and fall times of less than 2 ns, and an absolute delay of less than 4 ns, the Model 127D may be used to combine nanosecond pulses from as many as sixteen different sources. All inputs are terminated in 50Ω. Output is linear to ± 1.5 volts. Pulses may be applied separately or simultaneously to one or both channels; channel inputs and output at ground potential allow compatible interconnection between units. The current source output stage permits paralleling, by external cables, a large number of similar high-output impedance channels. The front-panel pushbutton MIXED switch connects Channel A output to Channel B output. The output amplitude of each channel is the algebraic sum of the input amplitudes. Neglibile stretching on overload allows use as a logic fan-in of NIM level inputs.

The LRS Model 127D is a member of the leading line of high-speed logic instrumentation in which modern circuit design, components, and packaging are combined in instruments of unusually broad usefulness to experimental physicists in both high- and low-energy nuclear research.

The LRS Model 127D is also available as the Model 127DL with Lemo-type connectors in a NIM #1 width module.

December 1971

Innovators In Instrumentation

LeCROY RESEARCH SYSTEMS CORPORATION · WEST NYACK, NEW YORK 10994 · TELEPHONE: (914) 358-7900

SPECIFICATIONS

NIM Model 127D/127DL

DUAL BIPOLAR LINEAR FAN-IN

INPUT CHARACTERISTICS

Inputs:	8 per channel; direct coupled. (Unused inputs need not be terminated.)
Impedance:	50Ω.
Polarity:	Positive or negative.
Reflection coefficient:	Less than 7% for inputs of 2 ns risetime.
Input protection:	±100 V, 10 usec

OUTPUT CHARACTERISTICS

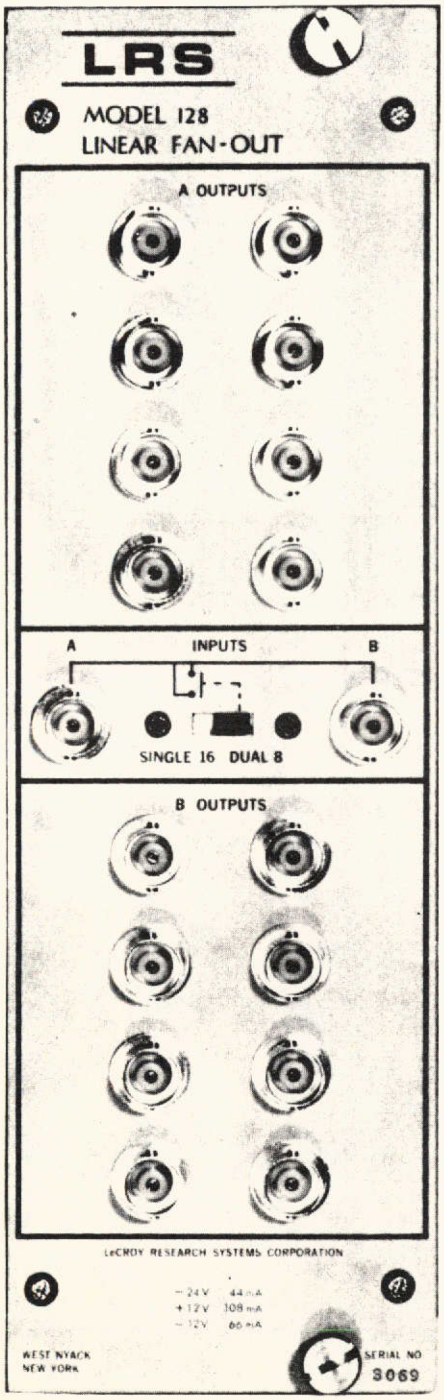
Outputs:	One per channel; direct coupled, current source.
Maximum Amplitude:	Linear region; ±30 mA. (±1.5 volts into 50Ω). Limits at ±40 mA (±2 volts into 50Ω).
Rise and fall times:	Less than 2.5 ns, 10% to 90%.
Gain:	Input to output: 1.0 into 50Ω (20 mA out per volt in.)
Duty cycle limitations:	None.
D.C. offset:	Adjustable with front-panel potentiometer.
Output stability:	Better than 0.5 mV/°C with 50Ω load.
Stage delay:	4 ns.
Overload recovery:	Approximately 1 ns with eight simultaneous NIM level (–800 mV) inputs.

GENERAL

Output mixing:	A front-panel pushbutton combines the outputs of the two 8-input channels to provide one 16-input channel.
Packaging:	Model 127D – RF shielded AEC/NIM #2 module; dimensions 2.75 x 8.75 x 10 inches deep. BNC connectors.
	Model 127DL – RF shielded AEC/NIM #1 module; dimensions 1.375 x 8.75 x 10 inches deep. LEMO - type connectors.
Power Requirements:	+24 volts at 25 mA, +12 volts at 165 mA, –12 volts at 150 mA, and –24 volts at 25 mA.

TECHNICAL DATA

LRS



NIM Model 128/128L

Dual Linear Fan-Out

The LRS Model 128 is a high-performance, economical, linear fan-out unit suitable for use with either logic or photomultiplier pulses. It offers two independent channels, each having unity gain and each having one input and eight isolated identical outputs. These two channels may be combined with a front-panel switch to provide a single 16-output channel. The Model 128 utilizes a direct-coupled, feedback-stabilized circuit design that provides excellent linearity, long-term stability, and uniformity of gain and pulse shape at all outputs. The speed of the unit is adequate for all common photomultiplier pulses and logic signals, and there are no duty cycle restrictions or rate effects.

FLEXIBLE, HIGH FAN-OUT
Two 8-fold channels, or one 16-fold channel.

EXCELLENT LINEARITY
Better than 1% integral.

WIDE AMPLITUDE RANGE
Linear to - 1.8V into 50 Ω.

DIRECT-COUPLED
No baseline shift at high rates.

INPUT PROTECTED
To ± 100 volts.

WELL-ISOLATED REVERSE-TERMINATED OUTPUTS

The LRS Model 128 is also available as the Model 128L with Lemo-type connectors in a NIM #1 width module.

August 1971

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SPECIFICATIONS
NIM Model 128/128L
DUAL LINEAR FAN-OUT

The LRS Model 128 is a dual-channel, 100 MHz, direct-coupled linear pulse fan-out offering a fixed gain of unity over its wide bandwidth. Each of the two independent channels accepts either standard fast logic signals or photomultiplier pulses directly, and delivers 8 identical outputs.

- Both input and output DC levels are at ground potential for easy interconnection with other direct-coupled circuits. A special built-in diode limiter circuit provides input protection against fast transients and a constant, matched 50-ohm input impedance to ± 100 volts.
- Each output is fully isolated from the others, and is reverse-terminated in 50 ohms. A choice of two independent 8-fold channels or a single 16-fold channel is available through a front-panel switch combining the inputs of the two channels. The high fan-out, in a completely direct-coupled circuit, gives the Model 128 a flexibility, stability, and general freedom from spurious rate effects not found in conventional circuits.

INPUT CHARACTERISTICS

INPUTS: One per channel; direct-coupled.

IMPEDANCE: 50 Ω, constant to ± 100 volts.

POLARITY: Negative.

INPUT PROTECTION: Withstands pulse inputs to ± 100 V without damage.

REFLECTION COEFFICIENT: Less than 7% at input amplitudes to ± 100 volts.

OUTPUT CHARACTERISTICS

OUTPUTS: 8 per channel; direct-coupled.

MAXIMUM AMPLITUDE: Negative: - 2 volts into 50 ohms; - 3 volts into open circuit; positive: + 100 mV into 50 ohms; + 150 mV into open circuit.

RISETIME: Less than 2.5 ns, 10% to 90%.

FALLTIME: Less than 3.0 ns, 90% to 10%.

GAIN: Input to any output: 1.0 into 50 Ω load, 2.0 into high impedance; uniformity between outputs on a single channel: ± 2%.

DUTY CYCLE LIMITATIONS: None.

OUTPUT STABILITY: Better than 0.5 mV/° C.

GENERAL

NON-LINEARITY: $<$ 1% over operating range of 0 to - 1.8 V.

STAGE DELAY: 3.4 ns.

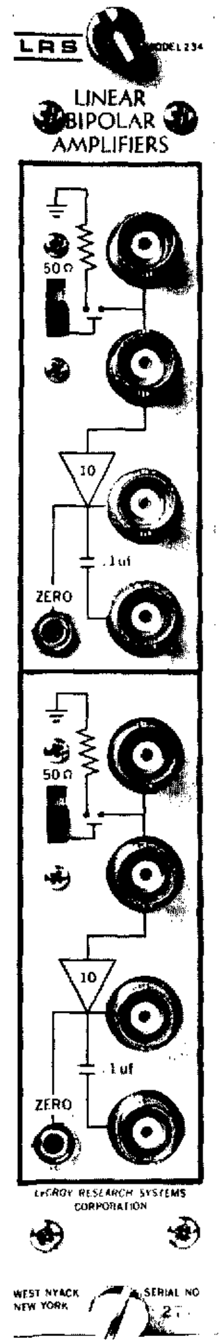
INPUT MIXING: A front-panel switch combines the inputs of the two channels to provide a single sixteen-fold fan-out channel.

PACKAGING: Model 128 — RF shielded AEC/NIM #2 module; dimensions 2.75 x 8.75 x 10 inches deep. BNC Connectors. Model 128L — RF shielded AEC/NIM #1 module; dimensions 1.375 x 8.75 x 10 inches deep. Lemo-type connectors.

POWER REQUIREMENTS: + 12 volts at 108 mA; - 12 volts at 66 mA; - 24 volts at 44 mA.

TECHNICAL DATA

LRS



NIM Model 234/234L

Nanosecond Bipolar Dual Linear Amplifier

LRS Model 234 is a dual-channel, 2-nanosecond direct-coupled pulse amplifier offering a fixed gain of ten for use in high-speed analog and logic systems. Each of the 234's two independent bipolar channels has switchable high input impedance with two paralleled input BNC connectors to make the input signal available for further use in a 50 Ω logic system. Both input and output DC levels are at ground potential for easy interconnection with other direct-coupled circuits. Separate capacitively-coupled outputs are provided where DC blocking is desired. A special built-in diode limiter circuit provides input protection and a constant, matched 50 Ω input impedance to ± 50 volts. The direct-coupled design, unique in a commercial amplifier of this gain bandwidth (2000 MHz), affords the rapid overload recovery, stable baseline, and general freedom from spurious rate effects that characterize the performance of this amplifier. Excellent linearity and stability are achieved through heavy feedback in an amplifier circuit of inherent high performance. This amplifier is also available with Lemo-type connectors (Model 234L).

The LRS Model 234 is a member of an integrated line of high speed logic instrumentation in which modern circuit design, components, and packaging are combined in instruments of unusually broad usefullness to experimental physicists in both high and low energy nuclear research.

FEATURES

* 2 ns risetime
* Direct-coupled design
* Low time slewing
* No baseline shift at high rates
* Bipolar operation
* Feedback-stabilized gain
* Rapid overload recovery
* Inputs protected to ± 50 volts
* High stability

August 1971

Innovators In Instrumentation

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SPECIFICATIONS
NIM Model 234/234L
NANOSECOND BIPOLAR DUAL LINEAR AMPLIFIER

INPUT CHARACTERISTICS

Impedance:	1 kilohm, or 50 Ω, switch selected.
Input Protection:	Withstands pulse inputs to ± 50 V without damage; DC limited by 250 mW terminating resistors.
Reflection Coefficient:	Less than 5% at input amplitudes up to ± 50 V.
Quiescent Voltage:	Ground.

OUTPUT CHARACTERISTICS

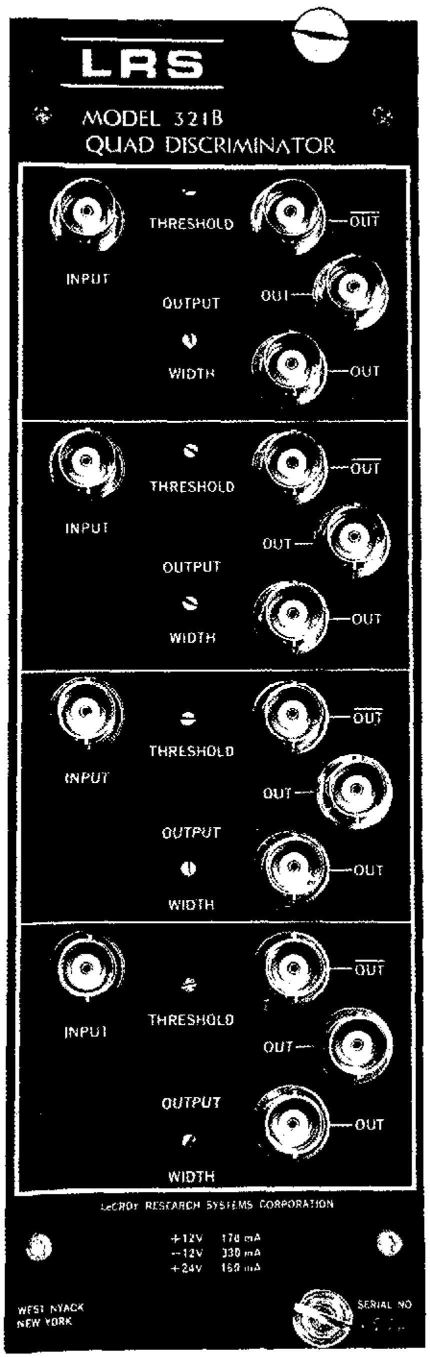
Impedance:	Approximately 6 Ω.
Maximum Amplitude:	± 2 volts.
Overshoot:	Less than 10%; less than 5% with 1 ns input risetime. Decays in approximately 3 ns.
Quiescent Voltage:	Ground.

GENERAL

Gain:	Fixed gain of 10, non-inverting. Long-term stability ± 1%. Gain tolerance ± 5%. Temperature dependence approximately 0.1%/° C.
Linearity:	2% integral.
Risetime:	1.6 to 2.0 ns, 10% to 90%. Variation with amplitude approximately 5%.
Delay:	In linear range, 4.0 ns, const. (3.0 ns circuit delay, 1.0 ns internal cabling delay). Slewing approximately 0.5 ns at 10-fold overload, 1.0 ns at 30-fold overload, and 1.2 ns at 60-fold.
Overload Recovery:	Less than 2 ns for 20-fold overload.
Noise:	Less than 50 microvolts rms, referred to input, total.
Bandwidth:	Direct-coupled, 0 to 200 MHz; AC-coupled, 30 KC to 200 MHz.
Packaging:	AEC #1 module. Model 234: BNC connectors. Model 234L: Lemo-type connectors.
Weight:	Module, approximately 1 lb.
Power requirements:	+ 24 V at 50 mA; - 12 V at 100 mA; + 12 V at 200 mA; - 24 V at 150 mA.

TECHNICAL DATA

LRS



NIM Model 321B/321BL

Quad Discriminator

Variable Threshold

LRS Model 321B Quad Variable Threshold Discriminator employs an outstanding circuit design to assure stable and reliable operation over a wide range of experimental conditions including variations in temperature, rate, pulse width, amplitude, risetime and supply voltage. It is an extremely versatile instrument, with threshold and other performance characteristics especially chosen for large scale, general purpose use in high energy physics. Compactly packaged, the 321B achieves a low unit cost through volume production techniques and without sacrifice of performance, quality, or flexibility.

Operational Features Include:

* **Continuously Variable Threshold** from 50 mV to 350 mV on Model 321B/50 and from 100 mV to 800 mV on Model 321B/100. A low minimum threshold permits proper back termination of phototubes or allows use of small, lower-gain photomultipliers without the necessity for a separate amplifier.
* **Threshold Stability** is <250 microvolts/°C, guaranteeing positive, reliable operation over varying experimental conditions.
* **Fiddle-free threshold and width controls** are screwdriver-adjustable. Recessed behind the front panel, they cannot be changed inadvertently during the course of an experiment.
* **Continuously variable output width** from 5 ns to .8 us is the widest continuous range offered by any discriminator in its class.
* **100 MHz operation:** The double pulse resolution of under 10 ns provides ample speed for most large-scale, general purpose applications.
* **High current outputs:** Each channel offers one −32 mA output split between two front panel BNC connectors (for fanout, terminating, or clipping,) and one −16 mA complementary output.
* **Output width is independent** of input duration, amplitude, and rate. No need for width cables, etc.
* **No multiple pulsing:** One — and only one — output pulse is produced regardless of input duration or amplitude.
* **Low time slewing** permits accurate timing even in experiments experiencing wide distributions of input amplitudes.
* **Deadtimeless operation** updates the output pulse to reflect the most recent input signal.
* **Compact packaging and low power consumption** permit up to 24 discriminator channels to be powered from one 72 watt NIM Bin.
* **Exhaustive quality control:** The threshold of each channel is checked for variation with input width, input risetime, rate, temperature, and supply voltage change to assure optimum performance and long, reliable service life.
* **Moderately priced** to appeal to today's larger experiments and smaller budgets.

January 1973

Innovators In Instrumentation

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SPECIFICATIONS
NIM Model 321B/321BL
QUAD VARIABLE THRESHOLD DISCRIMINATOR

INPUT CHARACTERISTICS**

Signal Input:	Threshold, – 100 mV to – 800 mV (Model 321B/100); or, – 50 mV to – 350 mV (Model 321B/50); continuously variable (front-panel screwdriver adjustment, screwdriver included); 50 Ω protected to ±50 volt transients; direct-coupled; reflections <10% for input pulses 2 ns risetime; stability <.25 mV/°C over 20°C to 60°C operating range; offset, 0 ±2 mV; offset temperature coefficient, approximately .01 mV/°C.
Gate:	Slow gate via rear connector, with rear panel ON-OFF switch; rise and fall times, approximately 50 ns; clamp to ground from +5 inhibits; direct-coupled.

OUTPUT CHARACTERISTICS

Outputs:	Three, NIM; one positive (quiescently – 16 mA, 0 mA during output), two negative (0 mA quiescently, – 16 mA during output).
Duration:	Continuously adjustable via front panel screwdriver control from 5 ns to >800 ns. Other ranges, i.e., 15 ns to 8.5 usec, may be obtained as an option.
Temperature Coefficient of Output Width:	<.05%/°C.
Rise and Fall Time:	Less than 2.0 ns, all outputs, 10% to 90%.

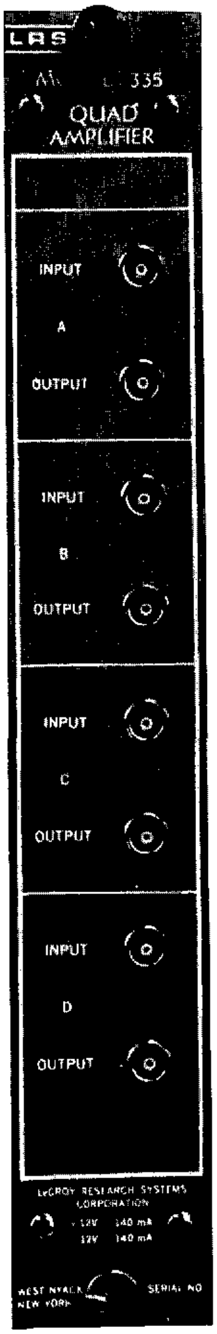
GENERAL

Maximum Rate:	110 MHz typical, input and output.
Double Pulse Resolution:	Approximately $T_0/3 + 5.5$ ns, where T_0 is output pulse duration.
Time Slewing:	<1 ns for input amplitudes 110% of threshold and above.
Input-Output Delay:	9.0 ns typical.
Multiple Pulsing:	None, one and only one output pulse of preset duration is produced for each input pulse, regardless of input pulse amplitude or duration.
Packaging:	In conformance with AEC standard for nuclear modules (AEC Report TID-20893); RF shielded AEC #2 module, fitting 6/bin; dimensions 2.75 x 8.75 x 10 inches deep. Completely compatible physically and electrically with LRS Power Chassis Model 108P, and with any other AEC power bin of any manufacturer.
Power Requirements:	+ 24 volts at 125 mA; – 12 volts at 300 mA; + 12 volts at 160 mA; all regulated ±.1%.
Total Power Consumption:	8.8 watts.

**Also available with two high impedance bridged inputs and fixed – 100 mV or – 50 mV threshold; respectively referred to as Models 321C/100 and 321C/50. LEMO-type connectors available on special order.

TECHNICAL DATA

LRS



NIM Model 335/335L

Quad Linear Amplifier

LRS Model 335 contains four high-speed pulse amplifiers which provide fixed, non-inverting gains of X6. The amplifiers are designed for use with either linear or logic signals of either polarity. The fast risetime (< 1.8 ns), low time slewing, and high stability make the Model 335 an excellent amplifier for use with high-performance photomultiplier/discriminator combinations.

The circuit of the Model 335 is completely direct-coupled and thus provides freedom from any baseline shift at high rates. Both input and output DC levels are at ground potential for easy interconnection with other direct-coupled circuits. An input protection circuit prevents damage from transient overloads to ± 10 volts. DC stability is less than 0.1mV/° C at the output, better than an order of magnitude improvement over previously available performance. Stage delay is nominally 1.5 ns, input to output.

The direct-coupled design, unique in an amplifier of such wide bandwidth, affords the rapid overload recovery (< 2 ns for 20-fold overload), stable baseline, and general freedom from spurious rate effects that characterizes the performance of this amplifier. The excellent linearity (better than 1% integral) and temperature stability are achieved through heavy feedback. The amplifiers are packaged in a single-width Nuclear Instrument Module (NIM) which conforms to the standards set forth in AEC Report TID-20893 (Rev.). The unit is also available with Lemo-type connectors (Model 335L).

The LRS Model 335 is a member of the LRS Innovator Line, an integrated line of high-speed logic instrumentation in which modern circuit design, components, and packaging are combined in instruments of unusually broad usefulness to experimental physicists in both high- and low-energy nuclear research.

December 1973

Innovators In Instrumentation

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SPECIFICATIONS
NIM Model 335/335L
QUAD LINEAR AMPLIFIER

INPUT CHARACTERISTICS

Impedance:	50 Ω .
Input Protection:	Withstands pulse inputs to ± 10 V without damage; DC limited by 250 mW terminating resistors.
Reflection Coefficient:	Less than 5% over input dynamic range.
Quiescent Voltage:	Ground.

OUTPUT CHARACTERISTICS

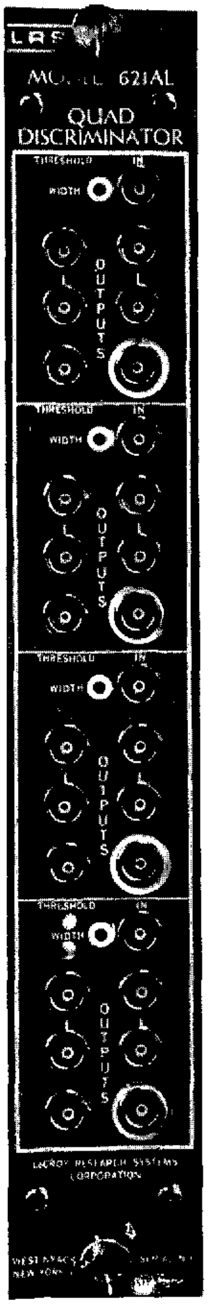
Impedance:	Approximately 6 Ω .
Linear Range:	+ 800 mV to -800 mV.
Maximum Amplitude:	+ 2 V to -1.1 V.
Overshoot:	Less than 15% with 0.8 ns input risetime.
Quiescent Voltage:	Ground, adjustable with internal potentiometer.

GENERAL

Gain:	Fixed gain of 6, non-inverting. Long term stability ± 1%. Gain tolerance ± 5%. Temperature-dependence approximately 0.1%/° C.
Linearity:	1% integral.
Coupling:	Direct.
Risetime:	1.8 ns, 10% to 90%.
Delay:	In linear range, 1.5 ns, const.
Overshoot:	< 15% with 0.8 ns risetime; less with slower inputs.
Noise:	Less than 100 microvolts rms, referred to input, total.
Power Requirements:	± 24 V at 50 mA, —12 V at 160 mA, +12 V at 150 mA.
Packaging:	AEC #1 module; Model 335: BNC connectors. Model 335L: Lemo connectors.
Weight:	Module, approximately 1 lb.

TECHNICAL DATA

LRS



NIM Model 621AL

Quad Discriminator

LRS Model 621AL retains the format and operating features of particle physics' most widely used discriminator, the LRS Model 321BL. A new hybrid input stage provides substantial improvement in input characteristics: an almost perfect impedance match to eliminate reflections and consequent multiple-pulsing; a drift-free -30 mV threshold; overload protection to withstand outputs from even the most serious phototube malfunctions; virtually no input dc offset; and a new standard of compactness and reliability. A threshold monitor test point is provided on each channel to permit accurate and reproducible threshold settings using an external DC voltmeter.

Output durations are adjustable from 5 ns to 1 us and are highly stable and independent of input amplitude, duration, and rate. Their long-term stability is excellent, permitting their direct use in critical coincidence applications without any need for external clipping cables. Each channel provides five standard amplitude negative NIM current source outputs and one complementary output. The flexibility resulting from this doubling of the output fan-out capability over previous circuits permits simpler and more efficient logic design. This greatly increased fan-out is achieved by means of a new output circuit design that utilizes very little quiescent power.

The -30 mV threshold offered by the Model 621AL is almost a factor of two lower than that of the most sensitive previous circuits. It will permit experimenters to routinely reverse-terminate photomultiplier anodes. This procedure, coupled with the greatly improved input termination characteristics of the 621AL, greatly reduces the possibility of multiple-pulsing due to input reflections in the system.

The pulse-forming circuit in the Model 621AL is deadtimeless (updating), and the unit may be retriggered during the time an output from a previous input signal is being produced.

The Model 621AL is also available with a bridged, high impedance input (at the expense of one negative output) at additional cost (Model 621AZ).

December 1973

Innovators In Instrumentation

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SPECIFICATIONS
NIM Model 621AL
QUAD DISCRIMINATOR

INPUT CHARACTERISTICS

Signal Input:	Threshold, -30 mV to -1.0 volt (continuously variable up to -600 mV); front-panel screwdriver adjustment (screwdriver included); 50 Ω protected to ±5 A for 0.5 μs, clamping at ±7 V; reflections <2% for input pulses of 2 ns risetime; stability <0.2%/° C over 20° C to 60° C operating range; offset 0 ±1 mV; threshold monitor has 10:1 ratio of monitor voltage to actual voltage.
Gate:	Slow gate via rear connector and real panel ON-OFF switch; rise and fall times, approximately 50 ns; clamp to ground from +5 inhibits; direct-coupled.

OUTPUT CHARACTERISTICS

Bridged Negative Outputs:	2 pair; NIM; quiescently 0 mA, -32 mA during output; duration, 5 ns to 1 μs, continuously variable up to 600 ns via front-panel screwdriver control (narrower widths possible at slight expense of amplitude); risetimes and falltimes typically 2.0 ns (max. 2.5 ns), 10% to 90%. Output falltimes slightly longer on wide output durations. Width stability better than ±0.2%/° C maximum.
Fast Negative Timing Output:	One; NIM; quiescently 0 mA, -16 mA during output. Other characteristics same as above, except risetimes and falltimes are typically ≤ 1.3 ns (max. 1.6 ns), and minimum width is ≤ 6 ns.
Complementary Output:	One; quiescently -16 mA, 0 mA during output. Other characteristics same as for Fast Negative Timing Output.

GENERAL

Maximum Rate:	110 MHz typical, input and output.
Double Pulse Resolution:	Less than 9 ns.
Time Slewing:	1 ns for input amplitudes 110% of threshold and above.
Input-Output Delay:	9.5 ns typical.
Multiple Pulsing:	None; one and only one output pulse of preset duration is produced for each input pulse, regardless of input pulse amplitude or duration.
Packaging:	In RF shielded AEC/NIM #1 module; Lemo-type connectors.
Power Requirements:	-6 V at 460 mA; + 6 V at 150 mA; -12 V at 165 mA; + 12 V at 20 mA; -24 V at 4 mA.
High Impedance Option:	The Model 621AL is also available with a bridged, high-impedance input (at the expense of one negative output) at additional cost (Model 621AZ).

ORTEC Technical Data

456 High Voltage Power Supply

September 1970

The 456, designed and fabricated at ORTEC, supplies noise-free, well-regulated, very stable high voltage necessary for proper operation of photomultipliers, ionization chambers, Li-drifted and surface-barrier semiconductor detectors, electron multipliers, and many other devices. The unit is housed in a **NIM* two-width module** that is suitable for mounting in either a NIM bin or on a bench top. The **low-noise output voltage** is continuously variable from ±10 to 3000 V with 0- to 10-mA output. Noise on the output is <10 mV peak to peak, thereby ensuring the highest performance in high-resolution semiconductor or scintillation spectroscopy systems.

The **front-panel meter** allows visual monitoring of the output voltage magnitude and polarity for the safety and convenience of the user.

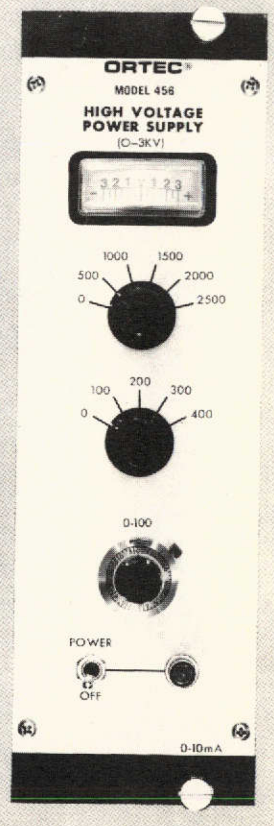
The **output voltage can be controlled** from ±10 to 3000 V by application of an external input dc level of 0 to ±11 V. This feature is desirable for control applications and is ***furnished standard*** on all units.

The input power for the 456 is taken directly from the ac line, either **110 or 220 V ac** 47 to 65 Hz. The unit has **no audible noise** and therefore can be operated in close proximity to users with no irritating, unpleasant ultrasonic or audio sounds.

The unique **overload and short-circuit protection** networks permit operation into short circuits or other unusually heavy-load demands with automatic, immediate regulation response upon removal of an abnormal load.

*TID-20893 (Rev.).

- **NIM bin package**
- **Low-noise output ±10 to 3000 V, 0 to 10 mA**
- **Panel meter**
- **Output controllable over full range by an external 0- to ±11-V input**
- **110- or 220-V ac input power**
- **No audible noise**
- **Overload and short-circuit protected**



SPECIFICATIONS

PERFORMANCE

OUTPUT VOLTAGE 10 to 3000 V dc.

OUTPUT POLARITY Positive or negative, selected by rear-panel switch or by polarity of external reference input voltage.

OUTPUT CURRENT 0 to 10 mA.

OUTPUT REGULATION ≤0.0025% variation in output for combined line and load changes within the operating range.

OUTPUT STABILITY Long-term drift of output voltage is <0.01%/hr, and <0.03%/24-hr period, at constant line voltage, load, and ambient temperature.

TEMPERATURE COEFFICIENT <50 ppm/°C, 0 to 50°C.

OUTPUT RIPPLE <10 mV peak to peak, dc to 50 MHz.

CALIBRATION ACCURACY Output voltage will differ from control settings by <0.25%.

RESETTABILITY Output voltage can be reset to within 0.1%.

OVERLOAD PROTECTION Internal overload and short-circuit protection with automatic output restoration; 12 mA absolute max output current.

METER Front-panel meter with center-scale zero to monitor output voltage and polarity.

CONTROLS

POWER Switch for main ac power input.

OUTPUT VOLTAGE Three front-panel controls to set output amplitude when rear-panel switch is set at Int; 0 – 2500 V in 500-V steps; 0 – 400 V in 100-V steps; 0 – 100 V with 10-turn duo-dial potentiometer; minimum warranted output 50 V, but satisfactory performance to 10 V min.

INT/EXT Rear-panel switch selects internal manual operation or external reference input to determine output voltage and polarity.

POS/NEG Rear-panel switch selects polarity of output for manual operation.

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456 TECHNICAL DATA

INPUTS

INPUT POWER 103-129 V or 206-258 V, 47 to 65 Hz, through 3-wire captive line cord with standard NEMA male connector.

EXT INPUT Rear-panel BNC connector accepts external reference input to determine output polarity and amplitude when Int/Ext control is set at Ext; 0- to ~9-V input produces 0- to ±3000-V output; Z_{in} >1000Ω.

OUTPUTS

OUTPUTS 10 to 3000 V dc; two rear-panel SHV connectors; AMP type 51494-2, ORTEC C-38. ORTEC mating C-36-12 cable available as accessory.

ORDERING INFORMATION

DIMENSIONS Standard double-width module (2.70 by 8.714 in.) per TID-20893 (Rev.).

WEIGHT (Shipping) 11 lb (5 kg).

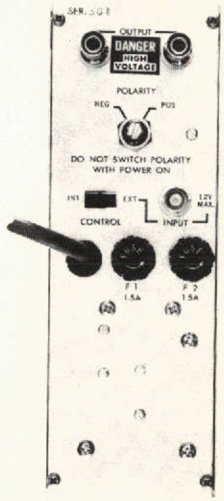
WEIGHT (Net) 8 lb (3.6 kg).

ACCESSORIES

ORTEC C-36-12 cable assembly; 12-ft RG-59A/U cable with SHV connectors on both ends to mate with 456 Outputs

ORTEC C-43 cable assembly; 12-ft RG-59A/U cable with SHV connector on one end and other end left blank for assembly of any desired connector.

ORTEC C-37 female SHV plug; AMP type 51426-2. (Note: requires AMP crimping tool type 90012 for assembly to cable.)



Rear Panel

C3

ORTEC
Technical Data

459
5KV Detector Bias Supply

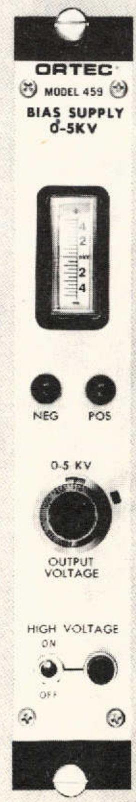
January 1971

The ORTEC 459 5KV Detector Bias Supply provides a bias voltage from a **NIM package** of **positive or negative polarity** for a semiconductor detector or for any type of detector requiring bias currents less than 0.1 mA; this includes proportional counters and ionization chambers. Two simultaneous outputs are provided, one for a range of **0 to 5 kV** and the other for a range of **0 to 500 V**. Both output voltages are controlled by a **5-turn direct-reading potentiometer** located on the front panel.

Either polarity is available through both outputs, with the polarity selected by an internal switch and indicated by a light on the front panel. A **panel meter** also monitors the polarity and the approximate voltage available through the output.

The 459 5KV Detector Bias Supply receives its necessary operating power from the ORTEC 401A/402A **Bin and Power Supply** in which it is installed for operation. All of the input power is supplied through the rear-panel module connector.

- **NIM bin package**
- **Positive or negative polarity**
- **0- to 5-kV and 0- to 500-V simultaneous outputs**
- **5-turn direct-reading control**
- **Front-panel meter**
- **Receives power from NIM Bin Supply**



SPECIFICATIONS

PERFORMANCE

BIAS VOLTAGE OUTPUTS Two output circuits, ranges 0 to 5 kV and 0 to 500 V.

BIAS CONTROL 5-turn direct-reading precision potentiometer.

BIAS POLARITY Either positive or negative for both outputs, selected by an internal switch and indicated on the front panel.

NOISE AND RIPPLE <10 mV peak to peak from 5 Hz to 50 MHz.

TEMPERATURE STABILITY <0.02%/°C through 0 to 50°C operating range.

VOLTAGE STABILITY <0.1%/hr output voltage variation with constant input voltages from Bin supply, constant temperature, and contant load.

OUTPUT CURRENT 0-100 μA.

OUTPUT VOLTAGE RISETIME 5 sec.

OVERLOAD PROTECTION Internal overload and short-circuit protection with automatic output restoration.

RESETABILITY Output voltage can be reset to within 0.2%.

CONTROLS

OUTPUT VOLTAGE 5-turn direct-reading potentiometer with 500 dial divisions adjusts output levels for both outputs simultaneously.

HIGH VOLTAGE ON/OFF Toggle switch and indicator lamp show when the instrument circuits are turned on to provide an output.

POLARITY +/- Internal switch selects either polarity for both outputs.

INPUTS

POWER All input power is furnished through the rear-panel module connector from the Bin and Power Supply.

REMOTE SHUTDOWN Rear-panel BNC connector; output voltage is reduced to zero by shorting the center contact to ground; Z_{max} of grounding circuit <30Ω.

459 TECHNICAL DATA

OUTPUTS

0-5KV (Z_0 = 2 MΩ) Rear-panel type SHV connector furnishes the adjusted output voltage in the 0- to 5-kV range through an output impedance of approximately 2 MΩ.

0-500V (Z_0 = 700Ω) Rear-panel type SHV connector furnishes the adjusted output voltage in the 0- to 500-V range through an output impedance of approximately 700Ω.

FRONT-PANEL METER Edge-reading meter monitors the polarity and output level for the 0- to 5-kV output range.

ELECTRICAL AND MECHANICAL

POWER REQUIREMENTS
+24 V, 57 mA; +12 V, 75 mA;
-24 V, 57 mA; -12 V, 75 mA.

WEIGHT (Shipping) 4 lb (1.8 kg).

WEIGHT (Net) 2 lb (0.9 kg).

DIMENSIONS Standard single-width NIM module (1.35 by 8.714 in.) per TID-20893 (Rev.).

ACCESSORIES

ORTEC C-36-12 cable assembly; 12-ft RG-59A/U cable with SHV connectors on both ends to mate with 456 Outputs.

ORTEC C-43 cable assembly; 12-ft RG-59A/U cable with SHV connector on one end and other end left blank for assembly of any desired connector.

ORTEC C-37 female SHV plug; AMP type 51426-2. (Note: requires AMP crimping tool type 90012 for assembly to cable.)

Rear Panel

ORTEC
Technical Data

485
Amplifier

December 1971

The ORTEC 485 Amplifier is a functional design utilizing integrated circuits to provide a general-purpose amplifier at minimum cost. The **low input noise**, gain range, and pulse-shaping networks allow operation with semiconductor detectors, proportional detectors, and scintillation detectors in a wide variety of applications. The performance capability of the 485 coupled with its low cost will allow a wide range of uses in such fields as research, counting rooms, monitoring applications, and instructional laboratories. Input and output connectors are provided on both front and rear panels for maximum convenience in a wide variety of applications.

Excellent **overload performance** is accomplished by the use of **pole-zero-cancellation** techniques. The cancellation network is compatible with all presently available preamplifiers. The pulse-shaping networks in the 485 produce an approximately **Gaussian-shaped** pulse which results in improved noise performance and also reduces the amplifier resolving time. The shorter resolving time permits higher counting rates than in amplifiers with classical pulse-shaping networks. The amplifier provides full- 10-V output with **either unipolar or bipolar** output.

This instrument is one of the ORTEC 400 Series of Modular Nuclear Instruments designed to meet the recommended interchangeability standards outlined in AEC Report TID-20893 (Rev.). An ORTEC 401/402 Series Bin and Power Supply provides all necessary power through the rear module connector. All signal levels and impedances are compatible with other modules in the ORTEC 400 Series.

- **Positive or negative input with low input noise**
- **Excellent overload characteristics**
- **Gaussian pulse shaping and adjustable pole-zero cancellation**
- **Full 10-V unipolar or bipolar linear output with matched gain in either mode**

SPECIFICATIONS

PERFORMANCE

SHAPING Active network filter resulting in approximately Gaussian shape, peak amplitude at 1.5 μsec for unipolar and 1.1 μsec for double clip; crossover at 2.5 μsec for bipolar.

NONLINEARITY ±0.15% over specified linear range.

MAXIMUM GAIN 640.

NOISE 10 μV at maximum gain and single clip, 12 μV at maximum gain and double clip, both referred to input at τ = 1 msec.

SHORT-CIRCUIT LIMITS Amplifier will sustain a direct short on the output for an indefinite period for counting rates up to 10^4 Hz.

COUNTING RATE <0.5% gain shift and 0.25% resolution spread FWHM for a pulser peak above a 50,000-count/sec ^{137}Cs background.

OVERLOAD Recovery within 2% of rated output from 600 times overload in 2.5 nonoverloaded pulse widths (25 μsec) at maximum gain and specified input.

CROSSOVER WALK ±3 nsec for 10:1 dynamic range with 1-μsec bipolar shaping (including Amplifier and ORTEC 420 Timing Single Channel Analyzer).

TEMPERATURE STABILITY 0.02%/°C, 0 to 50°C.

CONTROLS

COARSE GAIN A rotary switch with binary selection covers range of X2 to X64 in 6 steps.

FINE GAIN Provides a dynamic range of 3:1; selectable from X3 through X10, continuously variable.

PZ-TRIM A trim potentiometer permits pole-zero-cancellation network to be adjusted for varying preamplifier decay times.

POS-NEG A switch to accommodate either positive or negative input signals from a preamplifier.

UNIPOLAR-BIPOLAR Either unipolar or bipolar output pulses are switch selectable. The gains are matched in both modes to ~±2.5%.

INPUT

INPUT BNC (UG 1094A/U) connectors on front and rear panels accept either positive or negative pulses with rise times of 10 to 650 nsec and decay times of 25 to 2000 μsec; $Z_{in} \cong 1000\Omega$, dc-coupled; linear max 5.5 V; absolute max 12 V.

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485 TECHNICAL DATA

OUTPUT

BNC connectors on front and rear panels provide low-impedance shaped output. Unipolar or bipolar, 0 to 10 V linear with 11.5-V saturation into 1000Ω; $Z_0 < 1\Omega$.

RELATED EQUIPMENT

The 485 is compatible with all ORTEC transistor preamplifiers and other preamplifiers that have less than 12-V maximum output, 40-μsec decay time, and output isolated or at dc ground. The 485 can be used with all ORTEC single channel analyzers, discriminators, scalers with discriminators, biased amplifiers, and inverting or delay amplifiers and linear gates.

ORDERING INFORMATION

POWER REQUIRED

+24 V, 35 mA; +12 V, 50 mA;
-24 V, 35 mA; -12 V, 70 mA.

WEIGHT (Shipping) 5 lb (2.27 kg).

WEIGHT (Net) 2 lb (0.91 kg).

DIMENSIONS NIM-standard single-width module (1.35 by 8.714 in.) per TID-20893 (Rev.).

REAR PANEL

ORTEC
Technical Data

486 Amplifier–Pulse Height Analyzer

December 1971

The ORTEC 486 Amplifier—Pulse Height Analyzer (PHA) is a double-width NIM module that includes both a low-noise shaping amplifier and a window discriminator (single channel analyzer).

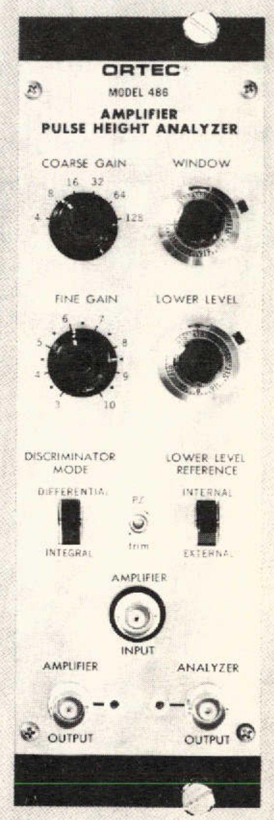
The Amplifier utilizes **active-filter shaping** for use with various types of radiation detectors. It is particularly well suited for use with proportional counters and scintillation counters normally used in x-ray and nuclear spectroscopy, as well as in x-ray diffraction and Mössbauer experiments. The **high gain improves operation of proportional counters** because they can be used with lower operating potentials, improving the gain vs count-rate stability. The short resolving time in the Amplifier provides a **high counting rate capability** without sacrificing the excellent resolution of proportional counters.

The Pulse Height Analyzer in the 486 incorporates an **active dc restorer** to maintain the peak in the window at high counting rates. This permits stable operation with a narrow window width and wide variations of count rate, as frequently encountered in x-ray diffraction experiments. Either Differential (window) or Integral mode operation is switch-selectable. The Lower Level Reference can be obtained either by the adjustment of the front panel precision potentiometer or by an external voltage from a mating ORTEC 487 Spectrum Scanner. A rear panel switch permits **selection of either a 10-V or a 1-V window range.**

The Analyzer Output (also called PHA Output) occurs ~150 nsec after the peak of the Amplifier output signal. The **walk of this signal is very small**, measured for a wide range of input amplitudes, and this feature makes the 486 ideal for use in slow coincidence or gating applications.

The External Lower Level input of the 486 accepts any dc or slowly varying signal level from an instrument such as an ORTEC 487 Spectrum Scanner. By using this control source, a narrow window setting for differential operation, and a ratemeter with either a digital or analog recorder, a complete swept spectrometer system is available.

- **Active-filter network for Gaussian shaping**
- **High gain for use with proportional counters**
- **High counting rate capabilities**
- **Active dc restorer in PHA**
- **Selectable window range**
- **Minimum walk of output signals**



SPECIFICATIONS

AMPLIFIER

PERFORMANCE

SHAPING Approximately Gaussian shape, peak amplitude at 0.8 μsec for unipolar and 0.7 μsec for bipolar; crossover at 1.3 μsec for bipolar; time constants nominally 0.5 μsec.

GAIN 12 to 1280 with coarse gain control of 4, 8, 16, 32, 64, and 128; fine gain continuous control of 3 to 10.

INTEGRAL NONLINEARITY ≤±0.15% from 0 to 10 V.

NOISE ≤11 μV rms at max. gain and unipolar; ≤17 μV rms at max. gain and bipolar output; both referred to input at $\tau = 0.5$ μsec.

TEMPERATURE STABILITY 0.02%/°C, 0 to 50°C.

COUNTING RATE STABILITY The gain for a pulser spectrum at 85% of full scale will change <±0.25% when modulated by 5×10^4 counts/sec of random signals from a ^{137}Cs source-detector combination with the photopeak at 70% of full scale.

OVERLOAD RECOVERY After a X500 overload, the Amplifier operated at full gain will recover to within 2% of the baseline within 2 nonoverloaded pulse widths for both unipolar and bipolar.

CONTROLS

COARSE 6-position switch, to select Coarse Gain factor for Amplifier; factors are 4, 8, 16, 32, 64, and 128.

FINE Single-turn potentiometer for continuous adjustment of Fine Gain factor from X3 to X10.

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486 TECHNICAL DATA

POS/NEG Rear panel slide switch selects polarity of Amplifier input.

UNI/BI Rear panel slide switch selects either Unipolar or Bipolar Amplifier output.

INPUT

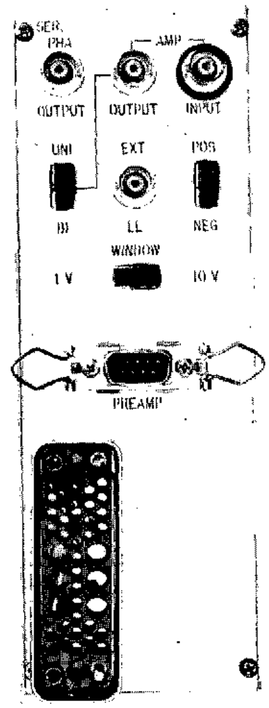
Positive or negative (switch-selectable on rear panel), 12 V absolute maximum, 1000Ω input impedance; pole-zero cancellation to match ORTEC preamplifiers; BNC (1094A/U) connectors front and rear panels.

OUTPUT

Positive unipolar or bipolar, with positive phase leading, 0-10 V linear range 12 V maximum; 93Ω driving source impedance on rear panel output, <1Ω driving source impedance on front panel output; BNC connectors (1094/U) front and rear panels.

PREAMPLIFIER POWER

Furnished through Amphenol Type 17-10090 connector on rear panel for operation with ORTEC-compatible preamplifiers.



REAR PANEL

PULSE HEIGHT ANALYZER

PERFORMANCE

OUTPUT TIMING Timed ~200 nsec from peak of output pulse from Amplifier. Walk (SCA output time shift vs amplifier output pulse height) <50 nsec for 50:1 change in output amplitude.

LOWER LEVEL Front panel adjustable from 0.1 to 10 V with 10-turn potentiometer; front panel switch selects external input on rear panel when used with ORTEC 487 Spectrum Scanner.

EXTERNAL LOWER LEVEL Input from 0 to -10 V, 1000Ω input impedance.

WINDOW 0 to 10 V or 0 to 1 V with front panel 10-turn potentiometer, range selectable by rear panel Window slide switch.

NONLINEARITY <0.25% of full scale (integral) for both discriminators.

PULSE PAIR RESOLUTION For lower level threshold ≥100 mV, ≤1-μsec pulse pair resolution over full dynamic range.

TEMPERATURE STABILITY ≤0.01%/°C, 0 to 50°C.

POWER SUPPLY SENSITIVITY Lower Level discriminator referenced directly to -12-V bin supply; Window discriminator referenced directly to +12-V bin supply.

CONTROLS

LOWER LEVEL 10-turn precision potentiometer for adjustment of Analyzer discriminator bias when using the Internal circuit; range 0.1 to 10 V.

WINDOW 10-turn precision potentiometer on front panel for adjustment of Analyzer window width when operating in Differential mode; range 0 to 1 V or 0 to 10 V, as selected by rear panel Window switch.

DISCRIMINATOR MODE Slide switch selects either Differential or Integral mode of operation for the Analyzer.

LOWER LEVEL REFERENCE Slide switch selects the source of Lower Level bias: Internal position selects front panel control; External selects signal through rear panel connector.

INPUT

Internally connected to amplifier output; impedance level of 1000Ω; input is dc-restored to provide <10-mV baseline shift at 100-kHz rate with full amplitude input signals.

OUTPUT

Nominally 5 V, 0.5 μsec wide, ≤10Ω driving source impedance; BNC connectors (1094/U) front and rear panels.

ORDERING INFORMATION

POWER REQUIRED

+24 V, 110 mA; +12 V, 150 mA;
-24 V, 45 mA; -12 V, 110 mA.

WEIGHT (Shipping) 5 lb (2.25 kg).

WEIGHT (Net) 3 lb (1.35 kg).

DIMENSIONS Double-width NIM instrument (2.70 by 8.714 in.) per TID-20893 (Rev.).

ORTEC
Technical Data

450
Research Amplifier

December 1971

The ORTEC 450 Research Amplifier is an extremely versatile instrument intended for use with all pulse-type radiation detectors and also for amplification of any frequency spectrum within bandwidth limits in the field of general instrumentation. The unit exhibits superior performance for overload recovery, resolution, linearity, and stability and has **ultralow input noise.**

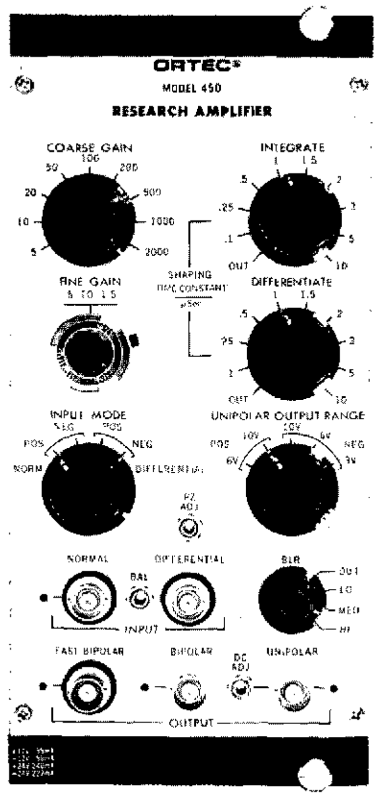
The many features of the 450 result in wide flexibility in application. The amplifier may be operated single ended or as a **gain-balanced differential amplifier**. This is especially useful when common mode noise is present. The low-frequency bandpass **(Integrate)** may be selected from **~100 Hz to 1.6 MHz**, while the high-frequency bandpass **(Differentiate)** may be **selected separately** over a range of 16 kHz to 1.6 MHz. The choices of **time constants** are in decimal sequence from **0.1 μsec to 10 μsec**, with additional values of 1.5 μsec and 3 μsec for optimization of Nuclear Spectrometry Systems.

The amplifier provides three distinctly different types of outputs. One, the **Fast Bipolar Output**, is a fixed bandwidth with a rise time of ~120 nsec and doubly differentiated to create a zero crossover point at approximately 700 nsec except in the wide-band mode, when the bandwidth extends from 100 Hz to >2 MHz with a variable gain of 2.5 to 3000. The second, the **Bipolar Output**, has both the high frequency and low frequency selectable. In the wideband mode the bandpass is from 100 Hz to 1.0 MHz. The third, the **Unipolar Output**, has selectable bandpass for optimum filtering; **baseline restoration** (if desired) for low-frequency noise reduction and improved count rate performance; polarity selection for system matching; and may be delayed to permit time-aligned gating of the signal. Here again, the bandpass is from 100 Hz to 1.0 MHz in the wide-band mode, and the gain extends to >5000.

The optimum signal-to-noise ratio is given by the Gaussian shaping of the active filter networks. The relative input noise at a 3-μsec time constant is approximately 3.0 μV and varies inversely as the square root of the time constant. The noise is independent of gain setting above a gain of 50.

All outputs are **protected against short circuits** and are capable of sine wave amplification to signal levels of 20 V peak-to-peak into a 100Ω load.

- **Ultralow input noise**
- **Differential input with pole-zero cancellation and gain balance**
- ***Independent selection of Integrate* and Differentiate**
- **Choice of 100 shaping-time-constant combinations**
- **Three outputs: Fast Bipolar, Bipolar, and Unipolar**
- **Built-in active baseline restorer**
- **All outputs protected against short circuit and excessive duty cycle**



SPECIFICATIONS

PERFORMANCE

GAIN RANGE 2.5 to 3000, for equal time constants, or 4.0 to 5000 for wide-band mode on Bipolar and Unipolar Outputs.

TEMPERATURE STABILITY 0 to 50°C.
Gain ≤±50 ppm/°C of rated output.
DC Level ≤±50 μV/°C.

INPUT NOISE Using 3-μsec pulse shaping, ≤3.0 μV rms for gain settings >50, measured on Unipolar Output; ≤16 μV rms on Fast Bipolar Output.

INTEGRAL NONLINEARITY
Fast Bipolar <0.2%.
Unipolar <0.05%.
Bipolar <0.05%.

CROSSOVER WALK ≤±2 nsec for 100:1 dynamic range, including contribution of ORTEC 455 *Constant Fraction Timing Single Channel Analyzer.*

COUNT RATE STABILITY A pulser peak at 85% of analyzer range shifts <0.2% in the presence of 0 to 5 x 10^4 random counts/sec from a ^{137}Cs source with its peak stored at 75% of analyzer range, using 1-μsec shaping.

OVERLOAD RECOVERY
Fast Bipolar Recovery from X500 overload in ~8.0 μsec.
Bipolar and Unipolar Recovery from X500 overload in 2.5 nonoverloaded pulse widths when PZ Adj is correct.
Filters Pulses are shaped by Active element, with independent Integrate (low-pass) and Differentiate (high-pass) selection.

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450 TECHNICAL DATA

CONTROLS

COARSE GAIN 9-position front-panel switch, for gain factors of X5 through X2000.

FINE GAIN 10-turn precision potentiometer, for continuously variable gain factors from X0.5 to X1.5. Product of Coarse gain and Fine gain settings yields total gain for equal time constants.

INPUT MODE Front panel switch selects Normal or Differential input and polarity.

INTEGRATE Front panel low-pass filter shaping-time-constant selector: choices are 0.1, 0.2, 0.5, 1.0, 1.5, 2.0, 3.0, 5.0, and 10.0 μsec and Out.

DIFFERENTIATE Front panel high-pass filter, shaping-time-constant selector: choices are 0.1, 0.2, 0.5, 1.0, 1.5, 2.0, 3.0, 5.0, and 10.0 μsec and Out (for wide-band with $\tau_d \simeq 3.5$ msec).

UNIPOLAR OUTPUT RANGE Front panel switch selects polarity and voltage range of 10, 6, or 3 V of the Unipolar Output.

BLR Front panel baseline restoration rate selector; Hi for duty cycles >20%; Med for duty cycles >5% <20%; Lo for duty cycles <5%; and Out.

PZ ADJ Front panel screwdriver adjustment to optimize amplifier to preamplifier, adjustable 35 μsec to dc.

BAL Front panel screwdriver adjustment to obtain optimum common mode rejection.

DC ADJ Multiturn screwdriver adjustment for Unipolar Output baseline; range ±1.0 V.

DELAY Normally 1 μsec, selected In or Out by rear panel switch. Other delays are available upon request.

INPUTS

NORMAL/DIFFERENTIAL Positive or negative, through front panel BNC connectors; ±12 V max; Z_{in} = 1000Ω, dc-coupled, with no limit on signal shape. For pulse operation fall time constant should be >35 μsec. Common mode rejection ratio ≥1000:1 at >1-μsec time constant, ≥10,000:1 at 60 Hz.

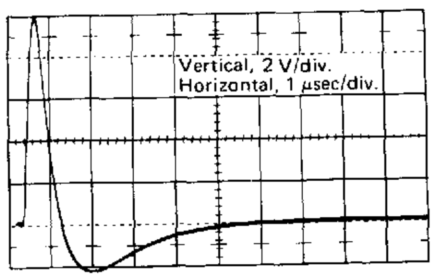
OUTPUTS

All signal outputs are on both front and rear panels. Z_o ≤1Ω, front panel, provides ±10 V into 100Ω load; Z_o = 93Ω, rear panel. All are dc-coupled and short-circuit and duty-cycle-protected BNC connectors.

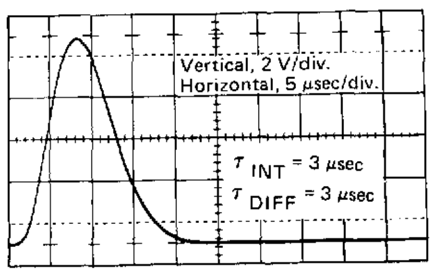
FAST BIPOLAR Bipolar; t_r ~ 120 nsec, gain 2.5 to 3000; crossover walk ≤±2 nsec for 50:1 dynamic range; with Differentiate Out, fixed bandwidth is 100 Hz to >2 MHz, gain 2.5 to 3000.

UNIPOLAR BNC (UG-1094/U) front-panel connector with Z_o <1Ω and rear-panel connector with Z_o = 93Ω, short-circuit proof; prompt or delayed with full-scale linear range of -3 V, ±6 V, or ±10 V; active filter shaped; dc-restored with selectable active baseline restorer rate; dc level adjustable to ±1.5 V.

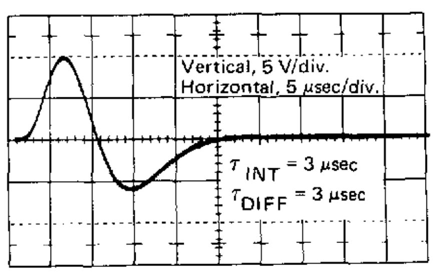
FAST BIPOLAR OUTPUT



UNIPOLAR OUTPUT



BIPOLAR OUTPUT



BIPOLAR When Differentiate selector is set at Out, f_{lo} ≈ 100 Hz. Low-frequency response set by two equal Differentiate selected time constants.

PREAMP POWER Standard ORTEC power connector for mating preamplifier; Amphenol type 17-10090; rear panel.

ORDERING INFORMATION

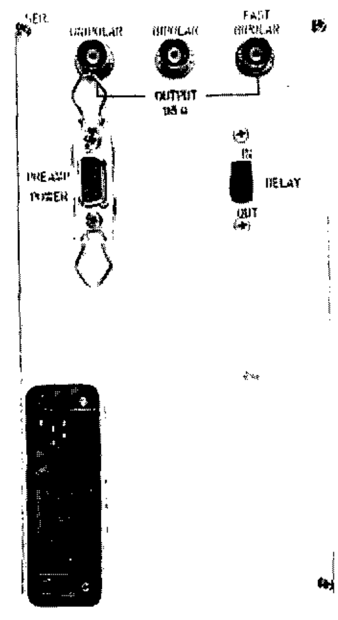
POWER REQUIRED

+24 V, 240 mA; +12 V, 55 mA;
-24 V, 220 mA; -12 V, 55 mA.

WEIGHT (Shipping) 7.5 lb (3.4 kg).

WEIGHT (Net) 5.5 lb (2.5 kg).

DIMENSIONS Standard triple-width NIM module (4.05 x 8.714 in.) per TID-20893 (Rev.).



REAR PANEL

SECTION 5

COMPATIBILITY OF NIM-CAMAC WITH THE SHUTTLE ENVIRONMENT

A preliminary analysis of the CAMAC modules and crates was performed to ascertain how they would meet the shuttle environment. Similar results also apply to NIM bins and modules. Since the CAMAC crates and NIM bins represent the lowest cost items of a NIM-CAMAC system, the approach was taken that any modifications should be incorporated in the crates and bins rather than the plug-in modules. The recommendations from this analysis were incorporated into a preliminary specification for Performance, Design, and Verification Requirements for Common Electronic Equipment for Shuttle Sortie Laboratory Experiments. The specification is provided in the Appendix.

5.1 MECHANICAL ANALYSIS

The CAMAC crate guide plates (upper and lower) and side plates assembly appear to be structurally sufficient except for a lack of torsional rigidity. The torsional rigidity can be provided by the rack by building in hard mounting points along the top and bottom of the side panels. There are two modes of mounting crates and bins: front panel attachment to vertical posts, and rail mounting along the bottom of the side panels. The front panel attachment gives a cantilevered support for the heavy power supplies at the rear of the crates and bins. A calculation of the dynamic stress this imposes on the crate or bin structure would require a finite element math model and an MRI Stardyne analysis to predict the loads. This was beyond the scope of this study, but because of the low torsional resistance of the crates and bins, rail mounting is recommended. The design of the rack will require a detailed structures analysis in a future program.

The CAMAC printed circuit (PC) boards are large compared to flight hardware. The natural frequency was calculated and compared with the vibration spectrum. The boards are approximately 200 mm (8 in.) by 300 mm (12 in.) by 1.5 mm (0.06 in.) thick, and with components weigh 0.4 kg (1 lb). The natural frequency (first mode) of a uniformly loaded plate is

$$f = C \sqrt{\frac{g E b t^3}{W (1 - \nu^2) a^3}}$$

where g is the acceleration of gravity, E is the modulus of elasticity (5×10^6 psi), a is the height, b is the width, t is the thickness, W is the weight, ν is the Poisson ratio (0.25), and C is a constant depending on the ratio of a/b and the edge mounting conditions. For all four edges simply supported, C = 1.47 and f = 67 Hz. For all four edges clamped, C = 2.88 and f = 131 Hz.

The PC boards will resonate between these extremes, since the actual edge conditions correspond to neither simple support nor clamped support, but somewhere in between. Figure 5-1 shows the orbiter mid-fuselage primary structure random vibration spectra, which is the best available estimate of the PC board environment. A resonance frequency between 67 and 131 Hz lies near the peak of the spectrum. The minimum level corresponds to an rms acceleration value of 5.3 g. At this level, even resonance at the peak frequency is not serious. The upper level corresponds to a relatively severe 14.7 g rms value, and amplification due to resonance could be destructive to board components.

The clearance between the module guide in the CAMAC crate and the module runner is 0.7 to 1.0 mm. This clearance permits considerable free movement of the metal-to-metal surfaces of the crate guide and module runner. Under vibration, this will increase the deflection at the resonant frequency and this clearance is not acceptable. A liner of resilient material would dampen the vibration and act as a loose clamp on the board edge to lower the resonant frequency. It is recommended that a liner be designed for the Space Shuttle crates and bins.

Other required mechanical changes are the use of threaded fasteners and a fixing (thumb) screw at the top of the module front panel. NIM-CAMAC standards do not control the application of threaded fasteners; some manufacturers use inserts and some do not. For flight application, the use of threaded fasteners should be in accordance with MIL-STD-454, requirement 12, particularly in the use of threaded inserts for fastening aluminum.

CAMAC modules have a fixing screw located at the bottom of the module front panel. Printed circuit board connector manufacturers agree that for flight application of edge board connectors, it would be necessary to include a second fixing screw at the top of the front panel similar to the NIM modules. The CAMAC standards for the crates make optional a threaded hole pattern on the top crate rail to accept NIM modules. Most manufacturers produce their crates with the same threaded hole pattern on the top crate rail as on the bottom rail. The top (fixing) screw is thus a change to only the module.

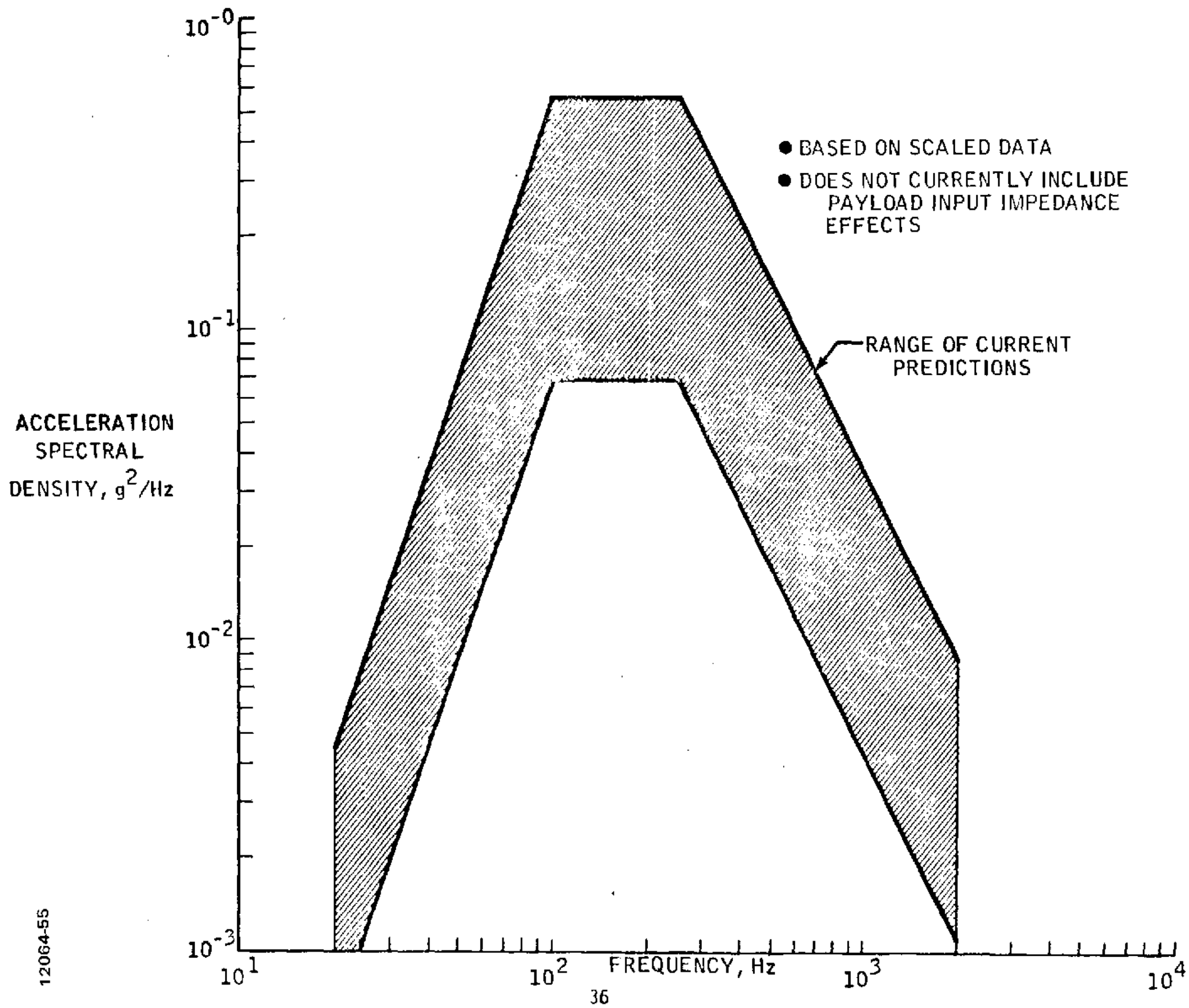


Figure 5-1 Analytical Predictions of the Orbiter Mid-Fuselage Primary Structure Vibration Spectra

5.2 THERMAL ANALYSIS

Thermal control of NIM equipment is accommodated by thermal convection or, with the addition of a blower, forced convection. Thermal control of CAMAC equipment is by forced convection utilizing a blower built into the crate. The equipment is designed to operate in a laboratory environment with an ambient temperature between 10 and 45°C.

Three user conditions were evaluated:

1. Crew or Sortie Lab compartment mounting with no heat exchanger. Ambient air is allowed at the blower intake and exhausted through the top and side of the rack holding the crates and bins.

2. Crew of Sortie Lab compartment mounting with a heat exchanger. The heat exchanger uses a Freon 22 loop provided by the Space Shuttle thermal control subsystem. Ambient air is allowed at the blower intake and exhausted through the top and side of the rack. The heat exchanger maintains the exhaust temperature nearly equal to the ambient air temperature.

3. Sealed compartment for Pallet mounting. The compartment is pressurized and the air recirculated and cooled to maintain air temperature within NIM-CAMAC specifications.

The major recommendations are that the air inlet be placed at the rear of the CAMAC crate and dummy modules be placed in all unused crate and bin slots. The rear air inlet is needed to duct the cooled air into the CAMAC crate in condition 2 listed above. Conditions 1 and 3 could use either front or rear air inlet. Unused module slots in either the bins or crates allow most of the forced air to leak through these openings. Dummy modules will block these openings and maintain the required pressure to force the air through the active modules.

5.2.1 Shuttle Cabin and Sortie Lab

The Shuttle cabin heat transfer environment is controlled by the Atmospheric Revitalization Subsystem (ARS) which is capable of a 21,500 Btu/hr heat removal rate. The cabin air pressure and temperature will be maintained at 14.7 psia and 65 to 80°F, respectively. The dew point temperature will range between 39 and 61°F so that condensation on equipment surfaces is precluded. Approximately 1,300 l/min (48 cfm) of air will be diverted from the ARS to provide life support for a four-man payload crew. Saturated air at 10°C (50°F) will enter the payload via ducting connecting the crew compartment with the space lab. After absorbing a maximum of 0.9 kW (3,000 Btu/hr), the air is exhausted back to the crew compartment. Support equipment, such as a Freon 22 coolant loop, will be available to provide auxiliary cooling of the NIM-CAMAC equipment located in the space lab.

5.2.2 Typical NIM-CAMAC Rack

For discussion purposes, a typical rack consisting of NIM-CAMAC equipment was arbitrarily conceived of that dissipated 1 kW (3,413 Btu/hr) based on the following assumptions:

Unit	Quantity	Actual Power Dissipated	Assumed Power Dissipated	Total Power Dissipated
CAMAC Crate	3	100 - 450 W ea.	300 W ea.	900 W
NIM Bin	1	50 - 160 W ea.	100 W ea.	100 W
			Total rack power dissipation	1,000 W

Figure 5-2 shows three CAMAC crates, one NIM bin, and packaged blower mounted in a standard rack. The NIM bin is located adjacent to the blower since it has no self-contained fans as do the CAMAC crates. Air is expelled from the packaged blower, routed vertically through the NIM bin, and passes individual PC cards in a parallel fashion. After exiting the NIM bin, air is drawn into each CAMAC crate by muffin fans. The present CAMAC crate has two or more muffin fans located in the front panel. For the Shuttle application, the fans should be moved to the CAMAC crate rear surface (shown in Figure 5-2) which will make possible the incorporation of CAMAC into a stored rack cooling scheme. After cooling the rack, air is either discharged to the ambient surroundings or recirculated within the rack to a heat exchanger, depending on whether the surroundings have the capability to directly absorb the heat load.

Highlights of a preliminary thermal analysis conducted on the typical NIM-CAMAC rack are as follows:

- The internal air flow rate and air pressure drop for the rack is 700 l/min (250 cfm) and 1.0 cm (0.40 in.) of water, respectively.
- The exit air temperature corresponding to an air flow rate of 700 l/min (250 cfm), a maximum inlet air temperature of 25°C (80°F), and a total electronic power dissipation of 1 kW is approximately 34°C (93°F).

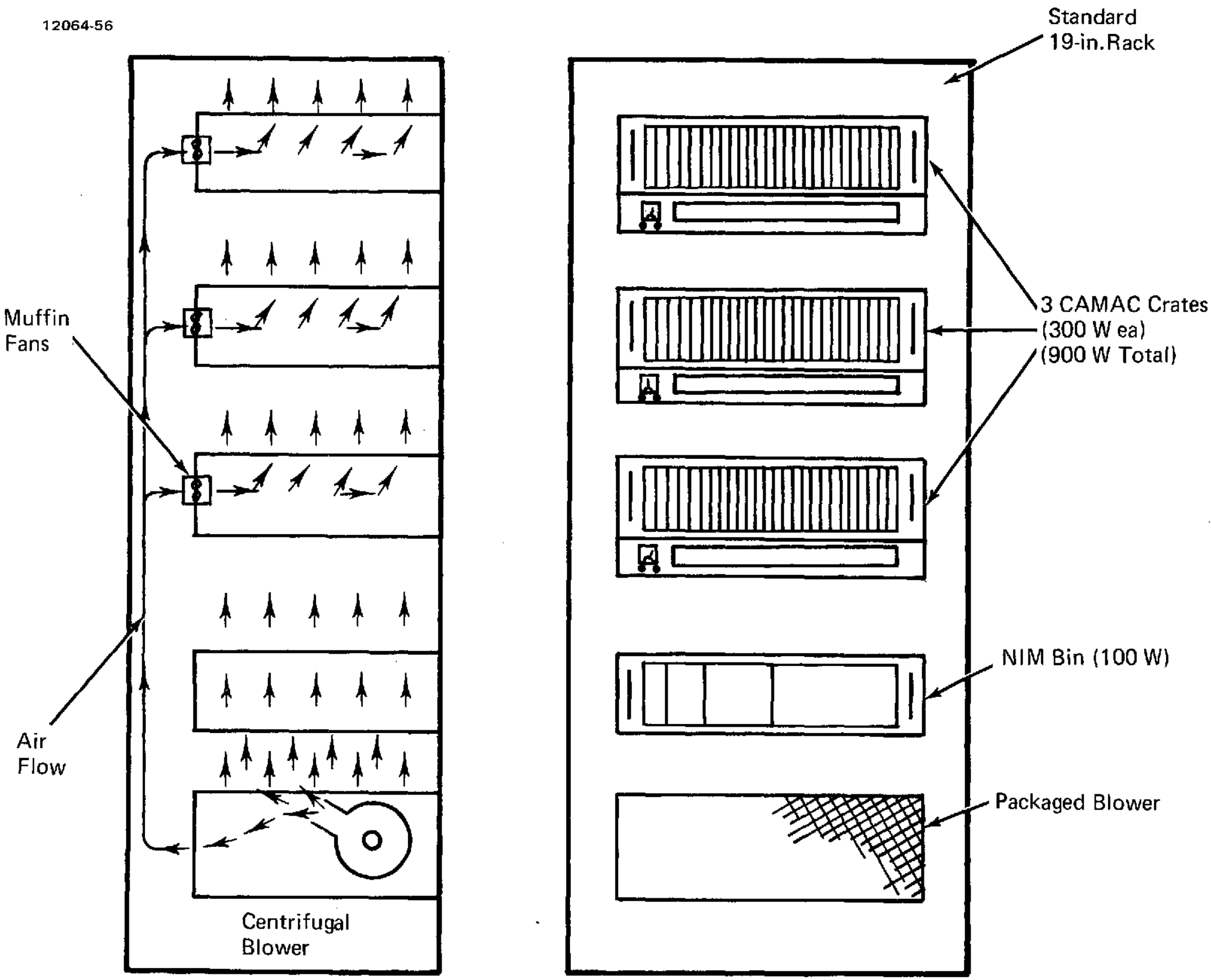


Figure 5-2 Typical Shuttle Sortie NIM-CAMAC Rack

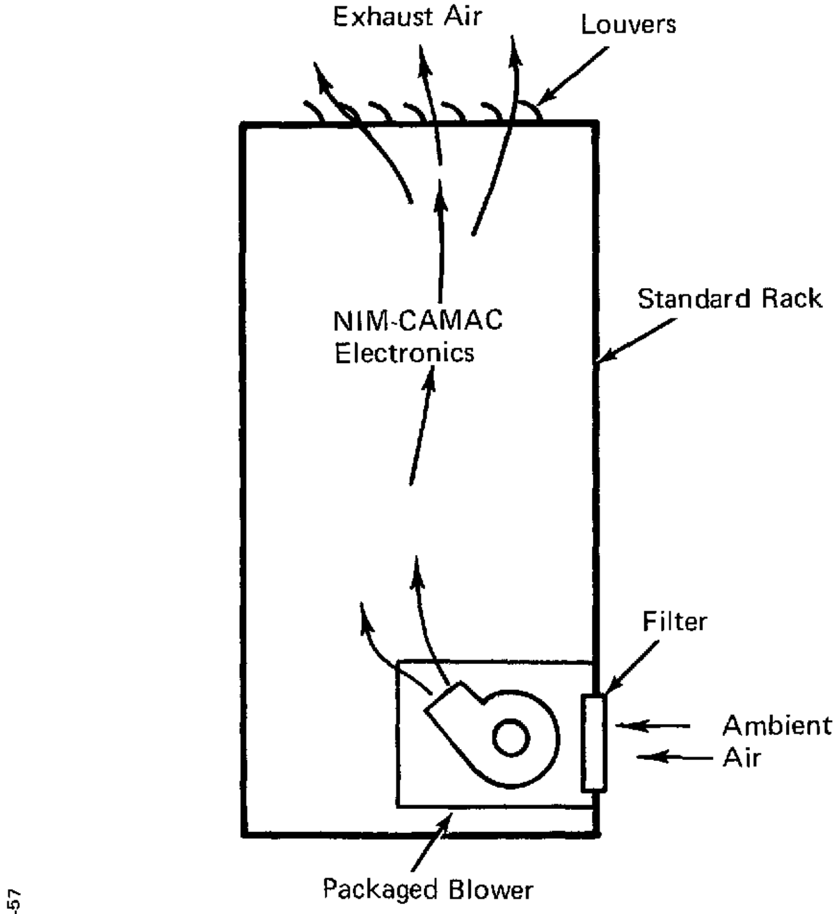
- The NIM-CAMAC packages contain temperature sensors which deactivate the equipment at 50°C (122°F). Since the maximum air temperature is 34°C (93°F), the possibility of over-temperature deactivation of the electronics is remote.

5.2.3 NIM-CAMAC Thermal Interaction with Shuttle

As shown above, the NIM-CAMAC packaging scheme can provide electronic part temperature control during the mission. However, Shuttle air-conditioning and cooling systems have a limited capacity. NIM-CAMAC power dissipation represents an additional demand above the environment control and life support heat loads which could perturb the overall Shuttle crew compartment's heat balance. Therefore, integration of NIM-CAMAC equipment into the Shuttle environmental thermal control and life support systems is critical. Aspects such as those discussed below must be considered.

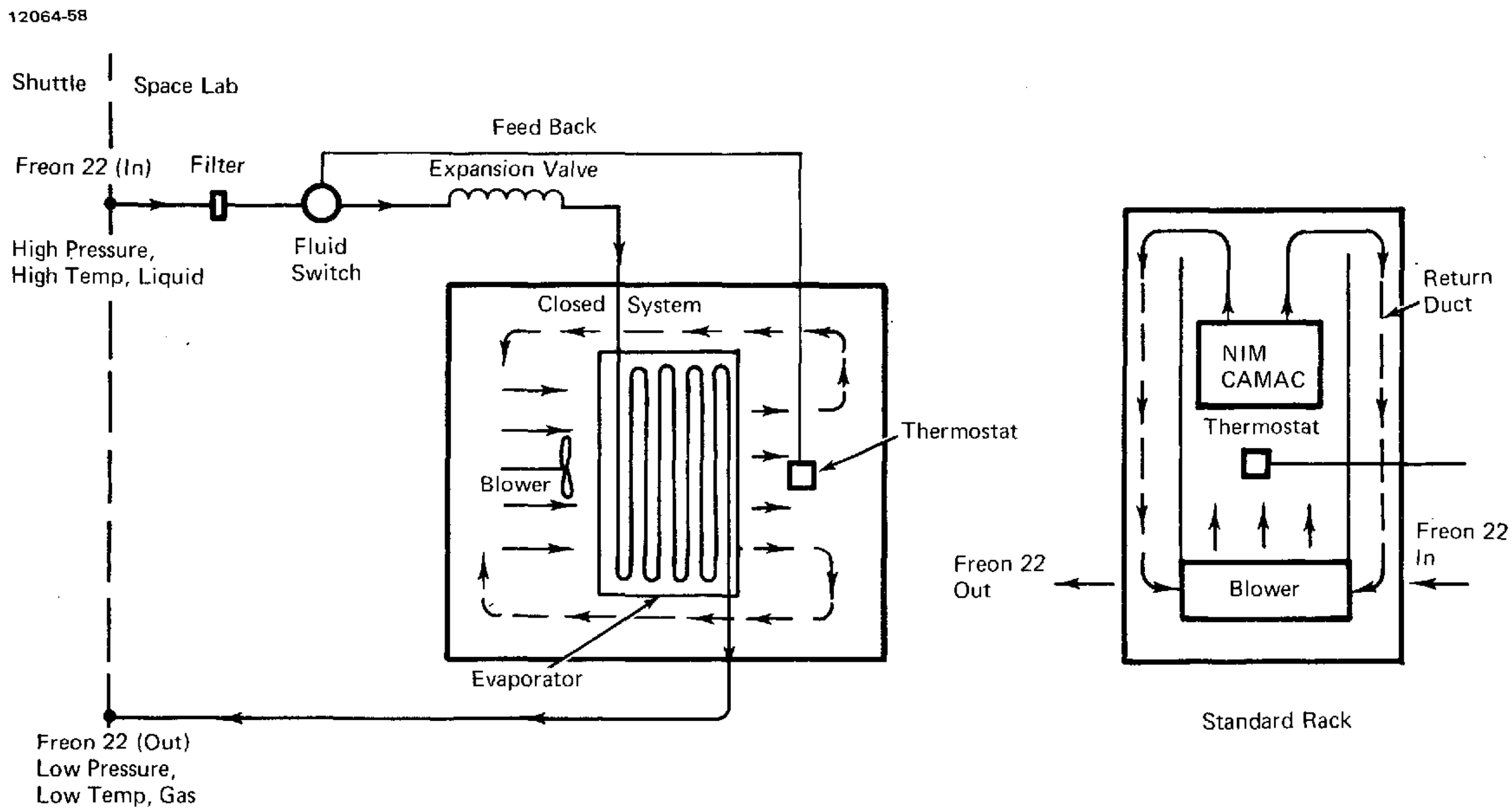
For NIM-CAMAC equipment located in areas where sufficient air conditioning may be available (i.e., crew area), the rack thermal design is shown in Figure 5-3. Filtered ambient air is drawn into the rack by the packaged blower and is expelled vertically. After cooling the electronics, the air is exhausted through the rack top surface. The rack is an open thermodynamic system rejecting heat directly to the surrounding ambient air which must be managed by the Shuttle environmental thermal control system.

In locations where addition of electronic power dissipation loads to the ambient may not be permitted (i.e., space lab and mounting in a sealed compartment on the pallet), auxiliary equipment will be available to provide NIM-CAMAC temperature control. A typical NIM-CAMAC rack cooled by a Freon 22 fluid loop (available on Shuttle) is shown in Figure 5-4. The rack is a closed thermodynamic system, which recirculates air and transfers electronic heat loads to the Freon 22 coolant through an evaporator heat exchanger. Cool air is propelled upward through the rack center and returned downward to the blower by ducts located on the rack lateral surfaces. A thermostat located within the rack inhibits Freon 22 flow when the coolant air at the evaporator outlet is less than 10°C (50°F).



NOTE: Environmental Control System Absorbs NIM-CAMAC Electronic Heat Load.

Figure 5-3 Open Rack Thermal Design



Notes:

1. Shuttle thermal control systems manage compression and condensation aspects of refrigeration cycle.
2. Thermostat set to inhibit Freon 22 flow at NIM-CAMAC coolant air temperatures of less than 50°F.

Figure 5-4 Closed Rack Thermal Design

5.3 NIM-CAMAC CONNECTORS

The NIM-CAMAC Dataway connector is a one-part (card edge) printed circuit connector. It consists of a receptacle containing stamped or formed contacts designed for use with a plug composed of contact tabs that are an integral part of the printed wiring conductor pattern. This type of connector presents a problem in Space Shuttle applications of NIM-CAMAC equipment because Military and NASA specifications prohibit the use of one-part PC connectors in flight equipment. This requirement is based on the following considerations:

- Environmental Considerations - An essential requirement to assure reliable operation of PC boards under the environmental conditions encountered in military applications is that the boards be thoroughly cleaned and protected with a conformal coating. Contamination is introduced on PC board surfaces through handling, storage, and exposure during operation. These contaminants may be conductive materials or organic materials that will support fungus. The presence of the contaminants on a board surface degrades the insulation resistance and can result in excessive electrical leakage or shorts between conductors. Protection of a board's clean surface by conformal coating precludes this degradation.

  Since the printed conductor contact tabs on the PC board that mate with the one-part PC receptacle cannot be conformally coated, use of this type of connector compromises the reliability of the equipment when exposed to environmental conditions encountered in military applications. The one-part receptacle also constitutes a moisture trap, which could further aggravate the condition.

  The environmental conditions to be encountered in the Space Shuttle application tend to minimize the problems associated with the environmental conditions in military applications. As a result of the relative short mission duration and controlled atmosphere, the problems attributed to contamination and corrosion due to exposure during use are reduced to a minimum. That the equipment is maintainable permits periodic cleaning of connector contacts between missions as required.

- Mechanical Considerations - A connector contact is a precision mechanical device where the two parts are normally manufactured to tolerances of ±0.001 to ±0.002 in. The spring member is designed to function over a 0.005 to 0.007-in. total excursion (including several mils of displacement necessary to activate the contact) without exceeding the elastic limit and taking a permanent set. PC boards are manufactured to a tolerance on the thickness dimension of ± 0.007 in. Thus, the card edge receptacle must be designed to assure positive contact over a range of approximately 4 times that required for normal two-part connectors. This condition is further complicated by the fact that the initial warp or twist permitted for PC boards is 5% with a total warp or twist of 10% over its life.

Another major factor affecting the reliability of the one-part connector is the divided responsibility of manufacture. The one-part PC receptacle is manufactured by a connector manufacturer to his detailed specifications. The manufacturer of the PC board portion of the connector plates the contact tabs to the customer's requirements. This condition makes it difficult to exercise the necessary quality control to assure reliable connector components.

- Electrical Considerations - The pins and mating contacts on edge board connectors are often misaligned during insertion and withdrawal. Shorts between the power bus and data connectors have occurred with CAMAC modules. This requires that personnel shut off the main power switch whenever a module is changed.

The quality control philosophy of two-part PC connectors is based on qualification tests and quality conformance tests using mating pairs of the connector as test specimens. This is necessary since it cannot be assumed that either half of the connector is free from fault. A similar quality control philosophy for the one-part connector is impractical, because it is manufactured by two different sources.

The quality control philosophy for one-part (edge board) connectors is normally patterned after the requirements of MIL-C-21097 using a PC test plug mated with the one-part receptacle during test.

The quality control philosophy for the two-part (plug and receptacle) PC connector is based on MIL-C-55302 using mating pairs of the connector during test. It is noted that contact resistance measurements are made before and after vibration and shock on the two-part connector, while contact resistance measurements are taken only prior to vibration and shock for the edge-board connector.

Discussions with connector manufacturers revealed that most of them are not aware of the existence of NIM-CAMAC standards even though their connectors are being used in NIM-CAMAC equipment. An example of this is the Viking 3PM43-9JND5 edge-board connector. Ortec Inc. of Oak Ridge, Tennessee, uses the Viking connector for the Dataway connector in fabricating NIM-CAMAC equipment;

however, the Viking representative had never heard of NIM-CAMAC. This condition could result in the use of connectors which do not comply with the NIM-CAMAC standards.

NIM-CAMAC equipment manufacturers indicate the major problems have been the insertion and withdrawal force of the Dataway connector. This problem, particularly associated with double-width modules, may be attributed in part to connector manufacturers not building connectors to the NIM-CAMAC standards. An example of this is the problem encountered by the Standard Engineering Corporation of Fremont, California. A Viking connector was being used as the Dataway connector. A force in excess of 22 kg (48 lb) was required to seat a double-width module. This force exceeds the NIM-CAMAC requirement of 80 newtons insertion force per PC board. The problem was resolved by having Pacific Connecting Devices design and fabricate an edge-board connector (P/N CDD-43B-2C) for the application. The Burndy Corporation is currently developing an edge-board connector (P/N PWBH4DD43-5) to meet the NIM-CAMAC standards.

Another problem with connectors encountered by equipment manufacturers and users is involved with the Hughes branch highway connector. The problem is primarily with a bent pin on the plug which damages the socket in the receptacle when mated. The damaged socket will bend the pin of a new plug when the connector is mated, and the fault progresses through the equipment as plugs and receptacles are interchanged.

The Dataway edge-board connector and the NIM adapter are not approved for flight applications by NASA or the military. The Viking edge-board connector (P/N 2VK43D/1-3), which is the same type connector as the NIM-CAMAC Dataway connector, is currently being used in Coast Guard flight equipment built by Bendix. To date, there have been no problems with this connector in the field. The operating environment for the Coast Guard application is much more severe than that of the Space Shuttle.

A 22-position, 44-contact edge-board connector from Stanford Applied Engineering (P/N SA-22D), which is similar to the NIM-CAMAC Dataway connector, is currently used in the Bendix M^2S equipment. The M^2S is also an aircraft application where the operating environment is more severe than the Space Shuttle environment. There have been no reported problems from field operations attributed to this connector.

To obtain approval for space flight applications, it would be necessary to subject a representative sample of equipment which utilize the NIM-CAMAC edge-board connector and NIM adapter to qualification tests that simulate launch and reentry environments. This qualification test would be designed to demonstrate that the connectors are capable of surviving launch, reentry, and functional operation during orbit.

Equipment suppliers would be required to extend NIM-CAMAC standard requirements to connector manufacturers in their procurement documentation to assure that connectors meet the standards.

5.4 GROUNDING

NIM-CAMAC standards allow for three-point grounding, chassis ground, signal return, and power return. Common practice is not to isolate these grounds. The signal return bus is not wired in the crate unless specified to the manufacturer. The practice of not isolating grounds has caused serious ground loop problems. Manufacturers are producing modules with optically isolated outputs to overcome ground loops. The alternative is to make isolated grounding mandatory.

5.5 MATERIALS

Two conditions govern the restriction on materials. If the NIM-CAMAC equipment is mounted in the habitable compartments, it must meet all the NASA offgassing and safety requirements. If the equipment is mounted in a hermetically sealed compartment on the pallet, then none of these restrictions apply. These two conditions are respectively referred to as Class 1 and Class 2 in the specification included in the Appendix.

Equipment for use in habitable environments must conform to the following requirements:

1. Materials which do not meet the flammability, odor, and offgassing criteria of NHB-8060.1 for Group 1 must be approved by JSC on an individual basis. Vacuum tests performed by Standard Engineering Industries showed that commercial NIM-CAMAC equipment could not maintain a vacuum because of outgassing. No identification of the gases was made.

2. Material which can shatter, such as glass, shall not be used unless positive protection is incorporated to prevent fragments or dust from entering the habitable environment.

3. Surfaces which are expected to be exposed to continuous or extensive abrasion and rubbing by the crew shall not be painted or coated with materials that are subject to flaking or peeling.

4. Equipment shall not contain mercury, liquid or gaseous halogenated hydrocarbons, or polyvinyl chloride (PVC).

5. Use of cadmium plating should be avoided in equipment containers subject to elevated temperatures (above 450°F) or where exposed cadmium in contact with breathing gas could reach temperatures that would generate toxic fumes such as might result from electrical short or fire.

6. All materials used shall be non-nutrient to fungus growth, or shall be treated so the exposed surfaces will be fungus resistant, except that nutrients may be used inside enclosures that will be hermetically sealed. Methods of treatment for fungus resistance shall be compatible with the treated and adjacent materials.

SECTION 6

NIM-CAMAC MANAGEMENT AT NATIONAL FACILITIES

NIM and CAMAC equipment is extensively used at national laboratories. Visits were made to the National Science Foundation (NSF) National Accelerator Laboratory (NAL) at Batavia, Illinois, the NSF Kitt Peak National Observatory (KPNO) at Tucson, Arizona, and the Los Alamos Meson Facility (LAMF) recently renamed the Clinton D. Anderson Meson Physics Laboratory at Los Alamos, New Mexico. All of these facilities maintain NIM-CAMAC pools for experimeter use, and their experience would be useful in establishing a NASA pool for Space Shuttle Sortie experiment payloads.

The NIM-CAMAC pools at NAL and LAMPF were similar as they both support high energy physics experiments. NAL is older than LAMPF and their pool is about 10 times larger. The NAL pool is $5 million worth of NIM-CAMAC equipment compared to the $0.5 million in the LAMPF pool. LAMPF also maintains a separate pool for in-house researchers, but as most experimenters have a LAMPF experimenter on their team, the equipment becomes intermixed. Both laboratories loan the equipment to the experimenter during the experiment buildup and he keeps the equipment until his experiment is completed. This period can be from 3 months to 2 years.

The management practices at the two facilities are slightly different. At NAL, after an experimenter receives approval for his experiment he prepares a list of the equipment he needs. The cost of the equipment and the duration of the equipment loan are established and he is issued a contract from NAL for the dollar amount of the equipment over the duration of the experiment. The experimenter is at liberty to change the mix of equipment he actually uses so long as the dollar amount and duration do not change. Small overruns (approximately 10%) in dollar amount and duration are tolerated. Large overruns must be renegotiated.

At LAMPF, the practice is to negotiate the list of equipment and hold the experimenter to his list. If an experimenter's requirements change, he has to renegotiate his needs. Each experiment is given a priority, and a high priority experiment can take equipment from a low priority experiment. Priorities change with time and usually become higher the closer the experimenter comes to running his experiment in the accelerator.

The NAL practice offers the experimenter more flexibility but requires a larger pool since needs are not controlled. Both facilities plan to expand their pools. Currently NAL supports about 30 experimenters and LAMPF supports 16 number one priority experiments and 11 lower priority experiments.

The Kitt Peak operation differs considerably from that used at high energy accelerator facilities. Most astronomers depend on Kitt Peak to provide standard instruments for their observation. Thus, the hardware remains reasonably constant. The variation from experiment to experiment is in data collection. Kitt Peak will vary real-time clocks, pulse counting and analog readout modes, scaler speed and capacity, and analog dynamic range and digitizing accuracy between experiments. A typical time to set up an experiment and check out new software is 3 hours. Installation time in the telescope requires about 2 hours. Typical duration of an experiment is 3 days.

Kitt Peak uses CAMAC exclusively to interface the telescope instruments to a computer. Each telescope installation requires only one crate. A typical crate configuration is slots 1-12 dedicated telescope control module; slot 13, input register; slot 14, output register; slot 15, quad scaler; slot 16, up/down counter; slot 17, eight-channel gate; slot 18, dual-channel timer; slot 19, digital oscillator; slots 20-21, display panel controller; slot 22, Dataway display; and slot 23, LAM grader. The first 12 modules are required for the telescope control and are not changed with instrument changes. The remaining modules are varied to interface different instruments. Kitt Peak has 12 crates, 11 for active use and one as a test bed in the Tucson laboratories.

Kitt Peak has developed their own approach for cabling. Cannon 36-pin ribbon connectors have been added to the back of each CAMAC module. These connectors are used for all input connections rather than front panel connectors. The Cannon connectors are wired into a patch panel, which is also connected to an instrument connector panel using heavy duty AN-type connectors. The instruments are connected by means of the AN connectors and the patch panel reassigns the wire routing between different instruments and the CAMAC module.

APPENDIX

GENERAL EQUIPMENT SPECIFICATION

PART I

PERFORMANCE, DESIGN AND VERIFICATION REQUIREMENTS FOR COMMON ELECTRONIC EQUIPMENT FOR SHUTTLE SORTIE LABORATORY EXPERIMENTS

CONTENTS

CONTENTS (Cont'd)

1.0 SCOPE

This specification establishes the general requirements for performance, design and verification of off-the-shelf analog and digital, modular electronic systems conforming to current NIM and CAMAC standards for scientific experiment applications in orbital operations in a pressurized compartment in Space Shuttle Sortie Pallet and Space Lab Missions. The detail performance and test requirements for a particular equipment shall be as specified in the detail specification for that equipment. Equipment which meets the quantitative performance requirements of this specification and which has particularly desirable attributes for a specific use shall not be rejected from further consideration due to failure to meet a qualitative requirement contained herein. Candidate equipment may be selected for modification or by limited waiver of requirements. Typical equipment which may be procured to these requirements is listed in Section 6.0.

1.1 CLASSIFICATION

The electronic equipment for which the general requirements for design and performance are outlined shall be of the following classes:

Class I - Equipment designed for operation in a habitable "Shirt-sleeve" Shuttle Spacelab environment.

Class 2 - Equipment designed for operation in a pressurized, unmanned Shuttle Sortie Pallet payload environment.

2.0 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between documents referenced and other detailed contents of this specification, the detailed requirements herein shall be considered superseding.

Specifications		Referenced Paragraph
Military		
MIL-F-14072A Sept. 11, 1968	Finishes for Ground Signal Equipment	3.3.9

Standards

Military		
MIL-STD-461A (Not. 4) Feb. 9, 1971	Electromagnetic Interference Characteristics, Requirements for Equipment	3.3.5.1
MIL-STD-462 (Not. 3) Feb. 9, 1971	Electromagnetic Interference Characteristics, Measurement of	3.3.5.1
MIL-STD-454D Aug. 31, 1973	Standard General Requirements for Electronic Equipment	3.3.6.1.5

Other Publications

NASA		
NHB-8060.1 Jan. 1972	Flammability, Odor, and Off-gassing Requirements and Test Procedures for Materials and Environments that Support Combustion	3.2.6.3
SP-3006	Bio Astronautics Data Book	3.3.15
CR-1205	Compendium of Human Responses to the Aerospace Environment	3.3.15
Atomic Energy Commission		
TID 20893 (Rev. 3)	Standard Nuclear Instrument Modules	3.2.1.1., 3.2.2.2
TID 25875 July 1972	CAMAC A Modular Instrumentation System for Data Handling Revised Description and Specification	3.2.1.1.1, 3.2.2.2
TID 25876	CAMAC Organization of Multi-Crate System	3.2.1.1.1, 3.2.2.2
TID 25877	Supplementary Information on CAMAC Instrumentation System	3.2.1.1.1, 3.2.2.2
TID 26488	CAMAC Serial System Organization	3.2.1.1.1, 3.2.2.2
Rules and Regulations Title 10, Part 71 Dec. 31, 1968	Packaging of Radioactive Material for Transit	3.2.7.3

Drawings

Atomic Energy Commission

NA-600	CAMAC Drawing List	3.3.1.2.2
ND-601	Unventilated Crate, Front View	"
ND-602	Plan View of Lower Guide in Crate	"
ND-603	Crate, Side View, Section	"
ND-604	Plug-in Unit, Side and Rear Views	"
ND-605	Dataway Connector	"
ND-606	Ventilated Crate-Front View	"
ND-607	Adapter for NIM Units	"
ND-608	Typical Printed Wiring Card	"
NA-500	NIM Print List	"
ND-503	Bin, Front View	"
ND-504	Bin, Rear View	"
ND-505	Bin, Side View	"
ND-506	Bin, Top View	"
ND-507	Module	"
ND-514	Connector Wiring	"
ND-517	Module Panel Adapter	"
ND-519	Connector Assemblies	"
ND-522	Power Supply Connections and Controls	"
ND-541	Standard Connectors and Hoods-Details	"
ND-545	Standard High Voltage Connectors	"

3.0 REQUIREMENTS

3.1 Definition

3.1.1 General Description

The common electronic equipment for Shuttle Spacelab and Pallet experiments shall consist of analog and digital modular electronic equipment to support experiments and experiment related activities and processes.

3.2 Characteristics

3.2.1 Performance

3.2.1.1 General Performance

3.2.1.1.1 Commercially available or off-the-shelf equipment and hardware conforming to NIM and CAMAC standards, AEC reports TID 20893 (Rev. 3), TID 25875, TID 25876 and TID 25877, shall be utilized to the fullest extent possible, consistent with the requirements stated herein.

3.2.1.1.2 Equipment covered by this specification shall not be required to be operating during launch, reentry or landing.

3.2.2 Physical

3.2.2.1 Mass Properties

Any limitations and restrictions are to be determined.

NOTE: A maximum weight of the equipment will be specified (specification weight).

3.2.2.2 Dimensions and Volumes

Equipment and equipment assemblies shall conform to the dimensions as specified in AEC reports TID 25875 and TID 20893 (Rev. 3).

3.2.3 Reliability

Non-catastrophic and non-propagating failures shall be permitted when compatible with individual experiment reliability goals.

3.2.4 Maintainability

3.2.4.1 The design shall provide for accessibility, rapid fault isolation, ease of remove/replace activities, and the use of standard tools and test equipment. Ground maintenance shall be the normal mode of maintenance.

3.2.4.2 Consideration shall be given to location of test points and adjustments for ease of maintenance without disconnecting electrical connectors.

3.2.4.3 Accessibility and ease of operation of latches, lockdowns, fasteners, etc., shall be considered for ease of maintenance.

3.2.4.4 For units or components requiring frequent adjustments, front panel access is desirable.

3.2.5 Operational Availability

Not Applicable.

3.2.6 Safety

3.2.6.1 The equipment shall not degrade the safety of the Sortie Lab, Space Shuttle, Ground or Flight Personnel or violate safety levels and requirements stated herein either during normal operations, maintenance or failure modes.

3.2.6.2 The equipment shall contain no ordnance devices.

3.2.6.3 For Class 1 equipment, all materials flammability, odor, and offgassing characteristics shall be identified for the application usage including relative locations, quantities and configurations. The atmosphere pressures and gas mixtures shall be as specified in 3.2.7.2 herein for on-orbit operations.

Any materials which do not meet the criteria of NHB-8060.1 for Group I must be approved by JSC for use on an individual basis.

3.2.7 Environment

3.2.7.1 Non-Operational
Class 1 Equipment:
Temperature: -40°C to +75°C (-40°F to +167°F)

Pressure: 0-15 psia, rate of change approximately 2 minutes from maximum pressure to minimum pressure.

Atmospheric Composition: 80% N_2, 20% O_2 ± TBD

Relative Humidity: 40-60% at 18°C to 29°C (65°F to 85°)

Acceleration: ± 4.5g (all axes)

Launch Status: Passive

Contaminants: Filter Air to Class 100,000 as defined in 3.3.10.1

Emergency Landing Shock: 8g Longitudinal, 4.5g Lateral, 4.5 g Vertical (Equipment need not operate thereafter, but shall retain package and mounting integrity.)

Vibration: 20-2000 Hz at a maximum of 14g rms composite vibrational level

Acoustic: TBD

Shock: TBD
Class 2 Equipment: TBD

3.2.7.2 Operational
Class 1 Equipment:
A nominal "shirt-sleeve" environment shall exist for equipment operation.

Temperature: 18°C to 29°C (65°F to 85°F)

Humidity: 45 ± 5% R.H. at 21°C (70°F)

Pressure: 14.7 psia ± 0.2 psi

Atmosphere Composition:

Total Pressure	14.7 psia
O_2 Partial Pressure	3.1 psia
CO_2 Partial Pressure	$<$0.15 psia
H_2O Partial Pressure	0.1-0.25 psia

Atmosphere Contamination:

Cleanliness: Class 100,000 as defined in 3.3.10.1

Maximum Methane Concentration $< 5 \times 10^{14}$ $\frac{\text{Molecules}}{\text{CM}^3}$
(10 PPM by weight)

Maximum Hydrocarbons (Molecular Weight > 200)

$< 10^{14}$ $\frac{\text{Molecules}}{\text{CM}^3}$

Acceleration: 10^{-2} g's

Vibration: TBD

Touch Temperature: 3°C to 46°C (38°F to 115°F). Equipment surface temperatures below 16°C (60°F) should be avoided to prevent atmospheric moisture from condensing on its surface.

Noise Level: Equipment and main equipment interfaces shall be compatible with an overall Sortie Module noise level less than the following:

Frequency Range (Hz)	Sound Pressure Levels
63	70 db
125	70 db
250	60 db
500	60 db
1000	55 db
2000	55 db
4000	55 db
8000	60 db
16000	60 db

Pure tone components shall be not more than 10 db above the octave band level containing the pure tone frequency.

Class 2 Equipment: TBD

3.2.7.3 Radioactive Sources. The quantities and/or concentrations of radioactive sources such as calibration sources and display dials shall not exceed the exemptions specified in USAEC Rules and Regulations, Title 10, Part 71, Paragraph 7.1.5. Also any equipment susceptible to radiation degradation shall be defined.

3.2.8 Transportability/Transportation

Equipment shall be compatible with commercial transportation systems.

Vibration and shock criteria - TBD

3.3 Design and Construction Standards

3.3.1 Selection of Specifications and Standards

Not Applicable.

3.3.2 General

Not Applicable.

3.3.3 Aeronautical

TBD

3.3.4 Civil

Not Applicable.

3.3.5 Electrical

3.3.5.1 Electromagnetic Compatibility (EMC) characteristics and measurements shall be in accordance with MIL-STD-461 and MIL-STD-462. The following frequency ranges shall be considered in establishing equipment emission and susceptibility levels. (Frequencies TBD)

3.3.5.1.2 Shorting clips or springs shall not be used in electrical or electronic connectors. Test equipment used shall be fitted with cable connectors that mate with the experiment equipment connectors or sockets. In no case shall socket connectors be connected by holding meter probes against the pins or by attachment of alligator clips. Miniature test points of the pin/jack variety are acceptable.

3.3.5.1.3 All electrical connectors, plugs and receptacles shall be positively keyed or tagged to prevent incorrect connection with other accessible connectors, plugs and receptacles.

3.3.5.1.4 There shall be safety interlocks where necessary to insure personnel safety.

3.3.6 Mechanical

3.3.6.1 Mechanical design shall generally meet the following requirements:

3.3.6.1.1 Class 1 equipment materials which can shatter, such as glass, shall not be used unless positive protection is incorporated to prevent fragments or dust from entering the habitable environment.

3.3.6.1.2 Class 1 equipment surfaces which are expected to be exposed to continuous or extensive abrasion and rubbing by the crew shall not be painted or coated with materials that are subject to flaking or peeling.

3.3.6.1.3 Where possible, actuating devices shall be made an integral part of the equipment to be operated. Detachable items, such as handles, pins, and ratchets, shall be secured by lanyards or similar devices which will not compromise crew safety.

3.3.6.1.4 Factors of Safety

3.3.6.1.4.1 Package integrity and structural mounting provisions load carrying capability shall be based on the following minimum factors of safety in lieu of performing static load structural testing:

Yield Factor of Safety	= 2.0
Ultimate Factor of Safety	= 3.0

3.3.6.1.5 Threaded fasteners shall be in accordance with MIL-STD-454 requirement 12. Threaded inserts shall be used when fastening soft materials such as aluminum. In areas where disassembly is infrequent or not required, self locking threaded inserts shall be used.

3.3.6.1.6 Modules shall have fixing screws at the top and bottom of the module front panel to retain module in its location in the crate.

3.3.6.1.7 Guides in the crate which accept module runners shall have a liner of resilient material to dampen vibration.

3.3.6.2 Materials

The following material requirements shall be in addition to the flammability, odor and offgassing requirements of paragraph 3.2.6.3 for Class 1 equipments.

3.3.6.2.1 Equipment covered by this specification shall not contain mercury, liquid or gaseous halogenated hydrocarbons, or polyvinyl chloride (PVC).

3.3.6.2.2 Use of cadmium plating should be avoided in equipment containers subject to elevated temperatures (above 450°F) or where exposed cadmium in contact with breathing gas could reach temperatures that would generate toxic fumes such as might result from electrical short or fire.

3.3.7 Nuclear

Not Applicable.

3.3.8 Moisture and Fungus Resistance

All materials used shall be non-nutrient to fungus growth, or shall be treated so the exposed surfaces will be fungus resistant, except that nutrients may be used inside of enclosures that will be hermetically sealed. Methods of treatment for fungus resistance shall be compatible with the treated and adjacent materials.

3.3.9 Corrosion of Metal Parts

Metals shall be corrosion resistant or shall be processed to resist corrosion. Dissimilar metals shall not be used in intimate contact unless suitably protected against electrolytic corrosion. Any protective coating used shall meet the requirements of paragraph 3.2.6.3.

3.3.10 Contamination Control

3.3.10.1 Class 1 equipment material or equipment finish shall not flake-off, generate dust or contain releasable particles that could degrade the class 100,000 spacecraft environment. All surfaces shall be capable of being cleaned with suitable solvents to maintain surfaces visibly clean. Class 100,000 environment is defined as not more than 100,000 particles, 1/2 micron in size or larger per cubic foot and not more than 700 particles, 5 microns in size or larger per cubic foot.

3.3.11 Coordinate Systems

Not Applicable.

3.3.12 Interchangeability and Replaceability

3.3.12.1 Interchangeability shall exist between identical replaceable parts, assemblies, subassemblies and supplies, regardless of manufacturer or supplier. All parts having the same part numbers, regardless of source, shall be functionally and dimensionally interchangeable.

3.3.12.2 Interchangeability of NIM and CAMAC digital and analog electronic modules and assemblies shall be assured by equipment conformance to the following drawings and/or specifications:

AEC Drawing No.	Title
NA-600	CAMAC Drawing List
ND-601	Unventilated Crate-Front View
ND-602	Plan View of Lower Guides in Crate
ND-603	Crate-Side View, Section
ND-604	Plug-in Unit - Side and Rear Views
ND-605	Dataway Connector
ND-606	Ventilated Crate - Front View
ND-607	Adapter for NIM Units
ND-608	Typical Printed Wiring Card
NA-500	NIM Print List
ND-503	Bin, Front View
ND-504	Bin, Rear View
ND-505	Bin, Side View
ND-506	Bin, Top View
ND-507	Module
ND-514	Connector Wiring
ND-517	Module Panel Adapter
ND-519	Connector Assemblies
ND-522	Power Supply Connections and Controls
ND-541	Standard Connectors and Hoods - Details
ND-545	Standard High Voltage Connectors

3.3.13 Identification and Marking

Major assemblies and replaceable units shall be adequately identified and marked.

3.3.14 Workmanship

Workmanship on all equipment (electronic, electrical and mechanical) shall be in accordance with good commercial practices and parts shall be free of burrs, sharp edges, or any other damage or defect that could make the part (or equipment) unsatisfactory for the purpose intended.

3.3.15 Human Performance/Human Engineering

Human performance/human engineering requirements shall be in accordance with guidelines contained in SP-3006, "Bioastronautics Data Book", and CR1205, "Compendium of Human Responses to the Aerospace Environment."

3.4 Logistics

Not Applicable.

3.5 Personnel and Training

Not Applicable.

4.0 VERIFICATION

4.1 General

Unless otherwise specified in the contract or purchase order, the contractor is responsible for the verification of all performance and design requirements contained herein and shall submit a written statement verifying that all requirements herein have been met. This verification statement is subject to approval and the procuring activity reserves the right to perform any inspection, operation or test deemed necessary to assure that material and services conform to the prescribed requirements.

5.0 PREPARATION FOR DELIVERY

The Contract End Items shall be prepared for delivery in accordance with the terms of the contract. Marking shall be adequate for proper identification. Preservation, packaging, packing, handling and shipping requirements shall be compatible with commercial transportation unless otherwise specified by the contractor. Any special unpacking or handling procedural requirements shall be defined by the contractor.

6.0 NOTES

6.1 Intended Use

The intended use of this specification is to procure common electronic equipment for support of Shuttle Space Lab experiments.

The analog and digital modular equipment to be procured by this specification is based on NIM and CAMAC design standards. Typical equipment includes but is not limited to the following:

Multiplexers
Code Converters
Analog-to-Digital Converters
Digital-to-Analog Converters
Time-to-Digital Converters
Pulse Generators and Clocks
Logic Function Modules
Crates
Ventilation Equipment
Scalers
Parallel Input Registers
Data Storage Modules
Display Modules and Units
Discriminators
Bins
Power Supplies
Power Cables
Digital System Control Modules
Printers
Amplifiers and Pulse Stretchers