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STATUS OF CAMAC IN NORTH AMERICA, 1975*

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Abstract

The latest developments in the application of CAMAC to the areas of laboratory equipment, industrial process control, aerospace, and medical electronics will be described. Formation and activities of the CAMAC Industrial Applications Group (CIAG) will be discussed. New trends in the applications of microprocessors in CAMAC will be emphasized. This paper is a follow-up to a prior status report presented at the First International Symposium on CAMAC.

LA SITUATION DU CAMAC EN AMERIQUE DU NORD, 1975

Résumé

Les développements les plus récents pour l'application du CAMAC aux installations de laboratoire, aux procédés industriels de contrôle, à l'aerospatiale, et à l'électronique médicale, seront décrits. On discutera de la formation et des activités du Groupe des Applications Industrielles CAMAC (CIAG). L'emphase sera mise sur les applications des microprocesseurs au CAMAC. Cet article constitut la suite d'un rapport précédent qui fut présenté au Premier Symposium International du CAMAC.

DER ENTWICKLUNGSSTAND VON CAMAC IN NORDAMERIKA, 1975

Abstrakt

Die neuesten Entwicklungen in der Anwendung von CAMAC auf den Gebieten von Labor Geraeten, industrieller Prozess Kontrolle, Luftfahrt und Medizin Electronik werden beschrieben. Die Gruendung und Taetigkeit der Gruppe fuer Industrielle Anwendung von CAMAC (CIAG) wird besprochen. Besondere Aufmerksamkeit ist neuen Tendenzen in der Anwendung von Microcomputern in CAMAC gewidmet. Dieser Bericht folgt einem frueheren Taetigkeitsbericht, der zum Anlass des 1. Internationalen CAMAC Symposiums veroeffentlicht wurde.

(Paper presented at the Second International Symposium on CAMAC in Computer Applications, Brussels, 14-16 October 1975)

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1. Introduction

Since the First International Symposium on CAMAC, steady progress in both user application and manufacturer support has been made in the United States and Canada.

In general, what one sees in applications is larger, more sophisticated, systems in laboratories, primarily using high-speed parallel techniques and widespread interest in industrial control applications, based on the use of the standard serial highway in bit serial mode, to replace expensive hardwired (direct wired) concepts. Both user groups see the importance of incorporating microprocessor technology into the CAMAC structure.

In manufacturing, some significant new developments have taken place, particularly in regard to serial system hardware, industrial control modules, expanded capability in laboratory instrumentation modules, and the introduction of microprocessors in CAMAC. Details of these developments, as well as activities of the various CAMAC committees and organizations, are the further subject of this report. A recent paper on the status of CAMAC (1) provided much useful information for this latest survey.

2. Significant Milestones

Several recent developments deserve special mention. One of the more significant recent developments is the IEEE acceptance of the basic CAMAC specifications (EUR 4100e, 1972, and the Supplement) as IEEE STD 583. This endorsement should do much to promote the broader use of CAMAC in commercial applications.

Another development of importance to the future of CAMAC is the commercial availability of Type L-1 serial crate controllers and associated serial system hardware. Figure 1 illustrates an example of a new version of the Type L-1 in a double-width module. Serial driver modules, both buffered (FIFO) and unbuffered, are also now commercially available.

A third significant milestone has been reached with the introduction of the first commercial microprocessor crate controller, shown in Fig. 2. It is based on the Intel 8080, and auxiliary DMA is available.

3. CAMAC Committee Work

Coordination between the NIM Working Groups and the ESONE Working Groups is very close, and thus there is no need to review in detail the activities of the NIM groups. As with ESONE, the primary goal of recent work has been to complete the work on the Serial System, and come to a stable point where the Serial System Specification can be rapidly completed. It is significant to point out that industrial representatives familiar with the Serial System were present during most serial subgroup meetings, and have been most helpful.

The System Compatibility subgroup has been primarily interested in the relation of CAMAC to other digital standards activities. Of particular interest is IEEE 488-1975 (HP Bus) which is a bit-parallel, byte-serial interface standard for programmable instruments. The subgroup is investigating the detailed characteristics of that bus and is planning to provide interface information between the HP bus and CAMAC, probably via a CAMAC module. An intelligent module of this nature is now under construction at Los Alamos and will be carefully considered by the subgroup. In this application, the HP bus is being used as a standardized bus structure for a control console where the use of a crate is somewhat inappropriate.

Other standards activities being monitored are EIA (Electronic Industries Association) for bit serial standards, and ANSI (American National Standards Institute) for the I/O channel interface and new minicomputer I/O standardization activities.

The Software Working Group has been working on Fortran subroutines for CAMAC, as well as following the ESONE activities on BASIC, in conjunction with efforts to produce a software handbook for CAMAC users.

Of great interest is the new activity on distributed control concepts in CAMAC. A new group, headed by Dr. Paul Kunz of SLAC, is coordinating this investigation and, as usual, every effort will be made to integrate this work with the parallel ESONE group. This work is extremely important for the future of CAMAC, for it relates both to the future applications in high-energy physics, which is becoming increasingly interested in rapid preprocessing of events, and to industrial control applications oriented around the serial highway, where local processing will be needed to reduce message traffic. In addition, the NIM Committee is now studying particular high-energy physics experiments implemented in CAMAC to suggest ways of increasing the data rate and coincidentally to guide the development of distributed control concepts.

4. IEEE Activities

It has become apparent that the extension of CAMAC beyond the laboratory applications would be considerably hastened by its endorsement by a broader organization. Based on prior history and contacts, the IEEE, an organization of practicing electrical and electronics engineers in all fields, was an obvious choice. A combined document was put together by the NIM Executive Committee comprising the basic specification TID 25875 and the Supplement TID 25877, and presented by Mr. Louis Costrell. After a period of study, the IEEE Standards Board approved the document as IEEE 583-1975 in June 1975. The IEEE will assume responsibility for future distribution of the document, and the previous government reports will eventually be discontinued.

It is felt that rapid endorsement of other CAMAC documents, particularly the serial system, is extremely important to the dissemination of CAMAC; thus the Parallel Branch and the Serial System are now in process through the IEEE. Due to the pressures of time, it has been necessary to submit the Serial System Description as an initial document, rather than wait for the formal specification document to be completed.

The adoption by the IEEE of CAMAC should prove very significant in broadening application areas for CAMAC, by pointing out to users and commercial interests that CAMAC is backed by a far broader group than the original nuclear laboratories. Furthermore, the availability of the documents should be more straightforward than the original government source.

The IEEE is also sponsoring periodic short courses on CAMAC in selected locations throughout the United States. These are tutorial in nature for beginning users and also serve as an interaction arena for general discussions of CAMAC activities. The IEEE has had courses in Boston, New York, Fermilab (Chicago), SLAC (Palo Alto, California), and recently in Atlanta, Georgia.

5. CIAG Activities

The CAMAC Industry Applications Group (CIAG) was formed about a year ago, and is headed by Dale Zobrist of ALCOA (Aluminum Company of America). Mr. Zobrist also participates in NIM-CAMAC meetings as CIAG liaison. The CIAG meets periodically to discuss CAMAC applications in industry, and has had discussions on technical matters of particular interest, such as on grounding and shielding. Both potential CAMAC users and CAMAC manufacturers are present. Demonstrations of bit-serial and byte-serial CAMAC systems have been held at these meetings, which have been coordinated with meetings of the Instrument Society of America, and the IEEE Industrial Applications Society.

Mr. Zobrist has for some time recognized that lack of full software support for CAMAC is a significant limitation in many applications. To this end, he is developing a "CAMAC Support Library for Industrial Systems."

6. Nuclear Laboratory Developments

As well as the routine application of CAMAC in data acquisition, many new developments are under way that greatly increase the sophistication and scope of CAMAC systems in the laboratories. Many of these, but certainly not all, involve the use of microprocessors and solid state memories.

For example, a new generation of CAMAC hardware is being installed at SPEAR (Stanford Positron Electron Asymmetric Ring), which includes many modes of DMA block transfers in the interface as well as high-speed LAM encoding. In addition, a microprocessor module using the Intel 8080 will be used to do pre-processing, data formatting, and driving an oscilloscope monitor. A block diagram of this system is shown in Fig. 3. An unusual characteristic is that the microprocessor module acts as both a module and a branch driver. It is via the latter function that the microprocessor has access to all the data in a branch. The potential size of the system is large—up to 16 branches are controlled by two "system crates."

The high-speed LAM encoding technique is a relatively straightforward solution to the rapid location of interrupts within a branch on a simple priority basis (2). Eight bits—three for the crate and five for the module—immediately vector to the highest priority location. A simple block diagram of this module is shown in Fig. 4.

A second-generation SPEAR solenoidal detector based on drift chambers is in design. The bulk of the data acquisition will be done with CAMAC modules. The system will include a fast secondary trigger system, or event selection, in CAMAC; hence fast preprocessing will be used before the slower conventional readout of the data into the computer.

At Fermilab, CAMAC has been used in sophisticated computer-to-computer links. Transmission is over 1- to 2-mile coaxial lines at a 4-MHz bit rate. The purpose of BISON-NET (3) is to supplement the local minicomputers in experiments with the computing power of a central CDC 6600, which has been equipped with a CAMAC branch. Block communication is then implemented between modules in remote crates and similar modules in the centralized CDC 6600 crate.

Fermilab has also inspired the commercial development of a sophisticated serial "driver" module (4), which resides in a crate driven by the parallel branch and drives the standard serial system. This module contains a FIFO memory buffer, and has four different operating modes, one of which loads serial highway commands into the FIFO. The intention of this work, of course, is to avoid making new custom interfaces for the serial system, by building on the existing parallel branch systems at Fermilab.

At SLAC, a CAMAC system has been connected to an IBM System 7 front-end computer for an expandable high-speed graphics capability as shown in Fig. 5. The System 7 computer is located remotely from a triplex of large IBM computers of the 360/370 class and is connected via high-speed coax. Tektronix 4013 graphics terminals are connected via modules with standard RS-232 ports, and a graphics refresh scope with light pen custom-built at SLAC is interfaced via a CAMAC module which contains a 1024-word memory. The same high-speed LAM encoding module referred to previously is used to rapidly identify interrupt sources. The system is operating successfully in a single-user mode, but a delay in multi-user software for the System 7 computer has prevented full operation. Eventually it is expected that smaller experimental computers will be linked to the 360/370 via this path.

CAMAC is being used in the laboratories for control and monitoring functions as well. At SLAC the DC precision constant current power supplies for a complete beamline have been automated using a Nova 1220 computer with remote CAMAC crates connected over a long parallel branch. (See Fig. 6.) Modules are very simple, and control is centralized for flexibility. User control and monitoring are provided via a conventional CRT monitor and ASCII keyboard. Eventually the system will be expanded to handle multiple users, and the parallel branch will be replaced by a serial link over the whole experimental area. One unique feature of the system is the use of photon coupled isolation boxes between the CAMAC crates and the AC controlled power supplies to prevent 1-kV fault voltages from entering the crates.

In another application at SLAC, a Nova 1220 computer is interfaced to a magnetic measuring system for automated measurement of magnetic fields. Figure 7 shows a view of the control console for this equipment. Recently a CAMAC 14-bit A to D converter was added to the system and, using the rotating coil method, harmonic analysis to better than .01 % has been achieved.

A system is under development at SLAC for the control of hydrogen targets in experimental systems. For this application, a self-contained microprocessor crate controller is being developed around an Intel 8080 to handle localized control with remote displays. The crate controller also can be connected into a branch for external computer access.

At Fermilab, a microprocessor crate controller for general-purpose control system work has been developed (5). In this case, the Intel 8080 is housed as a separate module, and the 8 data lines and 16 address lines are brought out to an external bus. The crate itself is controlled by a Type U crate controller which resides on the bus and appears as a series of memory locations.

Another microprocessor crate controller developed at Fermilab (6) is oriented towards the use of local intelligence in serial systems using the Serial Crate Controller (SCC). This crate controller can function either as an auxiliary or master crate controller, and is built around the Motorola 6800 microprocessor.

The role of microprocessors in physics research is of such current interest that an entire panel discussion in the upcoming Nuclear Science Symposium in San Francisco has been devoted to this subject. Titled "Applications of Microprocessors in Nuclear Research," the relation of CAMAC to microprocessors will undoubtedly arise, as well as the more specific but crucial question of fast pre-processing for event selection. In addition, there are many papers in the field of microprocessors in data acquisition and control, many of which involve CAMAC applications.

Drift chambers have become extremely popular detectors in high-energy physics. Most of the electronics at the national laboratories developed for drift chambers is in CAMAC modular form. In particular, a time digitizer scheme has been developed at Fermilab (7) which combines a time stretcher for the 4 low-order bits, and a conventional clock counter for the high-order bits. The result is 3-nsec time resolution and low module power dissipation.

In reference to the newest proposal for a high-energy facility at SLAC called PEP (Positron-Electron Project), it is not known whether CAMAC will be used in the control system, but CAMAC can be expected to receive heavy usage in the experimental areas.

7. Other Laboratory Applications

It is apparent that many other laboratories, with an environment similar to that of nuclear physics laboratories, will be implementing new systems in CAMAC when they are made aware of its potentialities.

At the laboratories of Gould, Inc., in Rolling Meadows, Illinois, a careful study of the current interface market for minicomputers indicated that for their purposes, CAMAC was found to be considerably less expensive than slower interfacing systems. A system has been developed for simultaneous operation of four analytical instruments using a separate crate in the CAMAC standard branch dedicated to each instrument. In terms of software (8), the system software is DEC RSX-11M, and the application software is Fortran with callable CAMAC I/O routines.

Some other laboratories using CAMAC are Atlantic Richfield Hanford Company in Richland, Washington, Bell Laboratories, University of Chicago Department of Geophysical Sciences (microprobes), and Kitt Peak National Observatory in Tucson, Arizona. At the Kitt Peak facility, ten separate telescope and/or data acquisition systems are operational. Computer-based systems are necessary to allow rapid initialization of instruments for observations, precise automatic tracking, and the collection of enormous amounts of digitized data during a typical experiment. CAMAC has proven useful in allowing rapid reconfiguration of systems and rapid connection of user-developed CAMAC instrumentation.

Probably the newest laboratory use of CAMAC is in the fusion research program in the United States. At General Atomic in San Diego, the Fusion Division is constructing a new plasma confinement machine called Doublet III, essentially a larger version of the well-known Tokamak machine, which will include a byte serial CAMAC system for control and monitoring. The system, scheduled for procurement in early 1976, will contain at least 8 crates, Type L-1 controllers, and possibly a microprocessor branch driver. The host control computer will be backed up by a similar computer with bus-switching capability, which itself will primarily serve to acquire physics and diagnostics data. In another section of the laboratory, a parallel CAMAC system is operational which is used for data acquisition of charge-exchange and X-ray experiment diagnostics, and further systems in laser experiments are planned.

At the Lawrence Livermore Laboratory (LLL), there are several laser fusion experiments in progress or in planning, which use CAMAC. JANUS and CYCLOPS are both 2-arm laser radiation facilities in which small CAMAC parallel systems are used with a PDP11/40 for acquiring of data from X-ray flux, light scatter, etc. ARGUS is a larger 2-arm system (eventually to be 4-arm) which will use local crates as well as an optically-isolated serial link to remote crates. The system again utilizes a PDP11/40 and includes interfaces for Reticon arrays for beam profiles, a streak camera, and graphics. ARGUS is essentially a prototype for an extremely large 20-arm 100-kJ system, which will utilize serial CAMAC with more than 30 crates. CAMAC will be used in both data acquisition and control (set up and pre-firing machine diagnostics). This system will use a PDP11/45 with a Type U to a system crate containing the serial driver. The system will take two years to become operational.

Similar applications in laser fusion research are taking place at Los Alamos Scientific Laboratory (LASL), and the Laboratory for Laser Energetics, University of Rochester.

At the General Electric Nuclear Fuel Facility in Wilmington, North Carolina, a CAMAC system is used for automatic inspection of fuel rods using an activation analysis technique. The facility is run by a Nova 800 series computer which does both data acquisition and control. An expansion of the system to incorporate additional quality control functions is being designed.

8. Industrial Applications

The attractiveness of CAMAC for commercial organizations is becoming apparent. In addition, commercial availability of serial system components has finally given these users the ability to construct systems without doing their own costly hardware development. One existing limitation is that full systems support from traditional suppliers is not yet readily available, although there are signs that such support is developing. Lack of full software support is, of course, a major factor in existing CAMAC systems.

Probably the most well known application is the ALCOA plant at Evansville, Indiana, where a 23-crate serial system controls 45 furnaces. Bi-phase modulation on coax cable with a backup loop and automatic switchover are employed, using loop collapse and bypass modules now commercially available. At the present time, the first crates are on line, and are being used for plant production.

In another application, the Electromotive Division of General Motors at La Grange, Illinois, uses the CAMAC Serial System with four remote crates as part of a new computerized test facility for diesel-electric locomotives. General Motors has apparently developed their own modules and serial driver for this system.

Inland Steel in East Chicago, Indiana, has several projects involving the CAMAC serial highway. The first is now in development and involves data acquisition and control on a slab caster some two miles distant from a PDP-11/45. One CAMAC crate is presently used to monitor 80 analog points, and the data is transmitted using an L-1 crate controller running at 4800 baud over telephone lines via conventional modems. This system is being controlled from a computer which currently controls a blast furnace, and it is planned to change the control and monitoring of the furnace over to CAMAC. General-purpose system software is now in preparation.

Another application at Inland, in the planning stage, utilizes 14 CAMAC crates connected by coax cable, scattered over some 25 square miles to monitor all utilities—electric, natural gas, oil—for centralized energy planning. In this system, no control functions are as yet planned.

Also in a design stage at Inland is a remote serial coaxial I/O system for control and monitoring of a new blast furnace. Whereas the previous applications are in-house systems, in this case specifications were written and are out for quotation among commercial system suppliers. Although not a specific requirement in the specifications, CAMAC is definitely being considered for this system.

The Electric Power Research Institute in Palo Alto, California, a research organization for U. S. utility companies, is funding a 15-month study of remote multiplexing for nuclear power plant applications. The results of this study are to be used to guide instrumentation techniques in future power plants of all types. The use of CAMAC will be included in the study as a possible candidate, along with other commercial systems and applicable technologies.

Other industrial applications in planning and/or evaluation testing phases are at ALCAN (Aluminium Company of Canada), Hydro Quebec of Montreal, Canada, Westinghouse Electric in Pittsburgh, and at General Motors in London, Ontario, all of which are based on the bit serial CAMAC highway.

9. Aerospace Applications

Several groups within NASA (National Aeronautics and Space Administration) have been considering CAMAC for various projects, including instrumentation of flight equipment for Space Shuttle experiments.

The Bendix Aerospace Systems Division has performed a study on the application of the CAMAC to the Space Shuttle experiment payloads and determined that 30% to 90% of electronic functions could be performed with commercial modules assuming minor packaging modifications are made (9). One obvious problem is that the Dataway connector is not flight qualified; similar connectors have been flown, however. In another paper on this subject (10), the authors also point out that dramatic cost savings will result from the use of CAMAC in spite of the fact that modifications are necessary such as lowering the power consumption. They caution that these positive viewpoints on CAMAC are not universal throughout NASA, however.

At NASA-Lewis Research Center, Cleveland, Ohio, engineers have implemented a standard serial CAMAC system designed to serve as a general-purpose data acquisition/monitoring and control link for different experimental facilities, from a central multi-tasking PDP-11 computer. The two facilities presently on-line are: (1) a solar panel test facility, in which various data such as temperature, power, and weather information are scanned periodically; and (2) a solar flux measurement facility in which various transducers are evaluated and compared. The systems contain commerical data acquisition modules such as ADC's, scalers, etc., and the serial link is driven by a commercial driver module in a system crate interfaced by a Type U crate controller. The system utilizes RSX-11D multi-tasking software, and includes implementation of Purdue Workshop standard FORTRAN calls for the display system. The serial link comprising twisted pairs (bit serial) at present is approximately one mile long and has been tested at bit rates of 100 kilobaud. Error rates and overall system performance are reported to be excellent.

CONCLUSION

As can be seen, many significant developments have taken place in the CAMAC world since the last report at this Symposium. Probably the most significant is the arrival of commercial hardware for the standard serial system which has spurred applications in the industrial area. On the other hand, the emergence of microprocessors has opened the door to far more sophisticated systems in laboratory applications. The recent adoption of the basic CAMAC specifications by IEEE is, of course, another significant milestone in broadening the scope of CAMAC.

Important issues to be answered which will affect the future of CAMAC are the question of software availability and support for total CAMAC systems, and the ease of incorporating distributed control into CAMAC for high-speed laboratory applications and low-speed industrial applications using the serial highway. These are both issues which the CAMAC Committees are now working on, and hopefully will resolve in the not too distant future.

Acknowledgments

Needless to say, a survey paper of this type depends completely on the many individuals in laboratories and companies who are doing the challenging work described, as well as generously providing information. In particular, the authors thank Dick Mack and Lee Wagner of Lawrence Berkeley Laboratory for providing information through their recent excellent paper on the subject, and Dale Zobrist of ALCOA for providing many important contacts in industrial applications of CAMAC.

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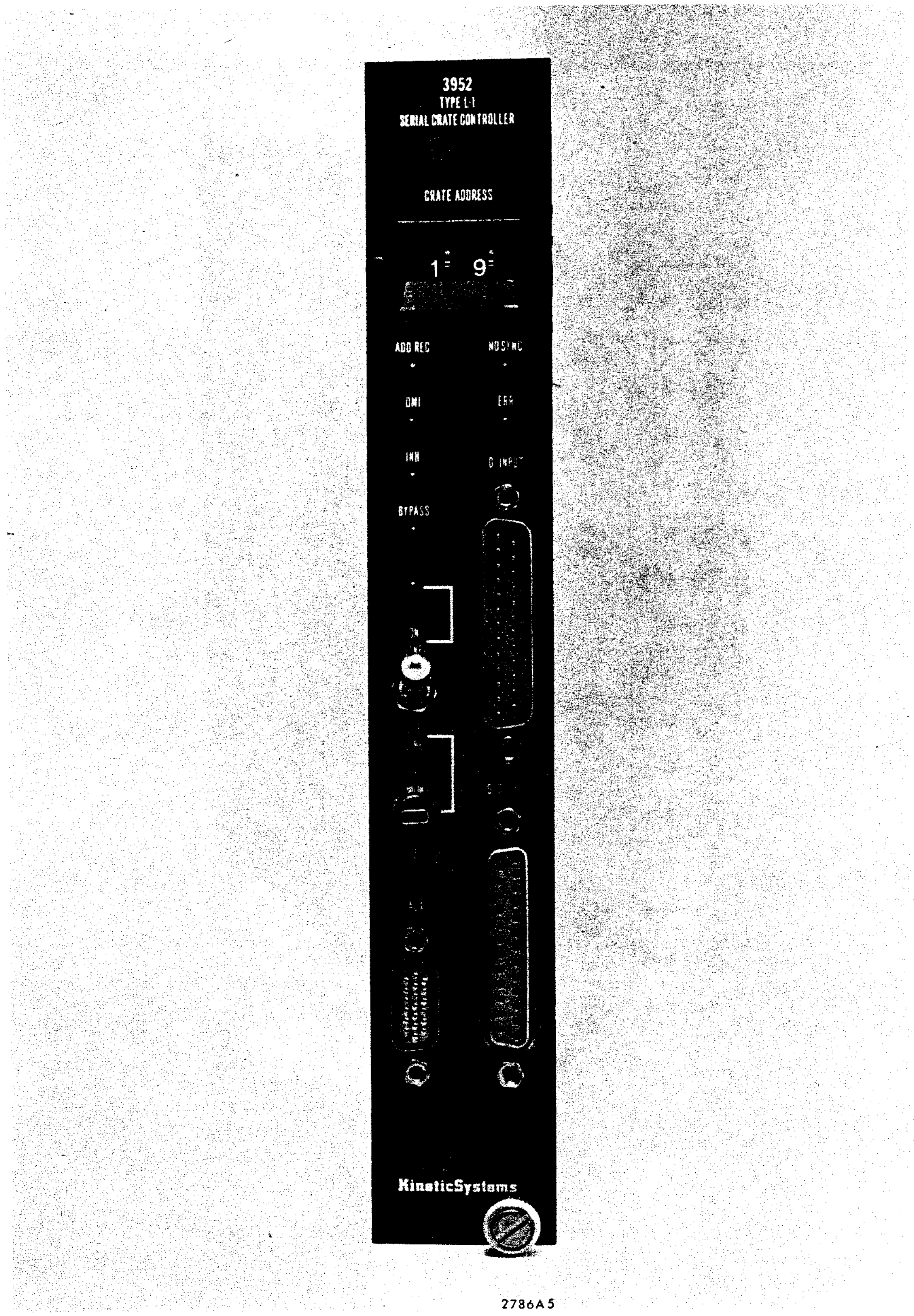
List of Figures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2786A5

Fig. 1

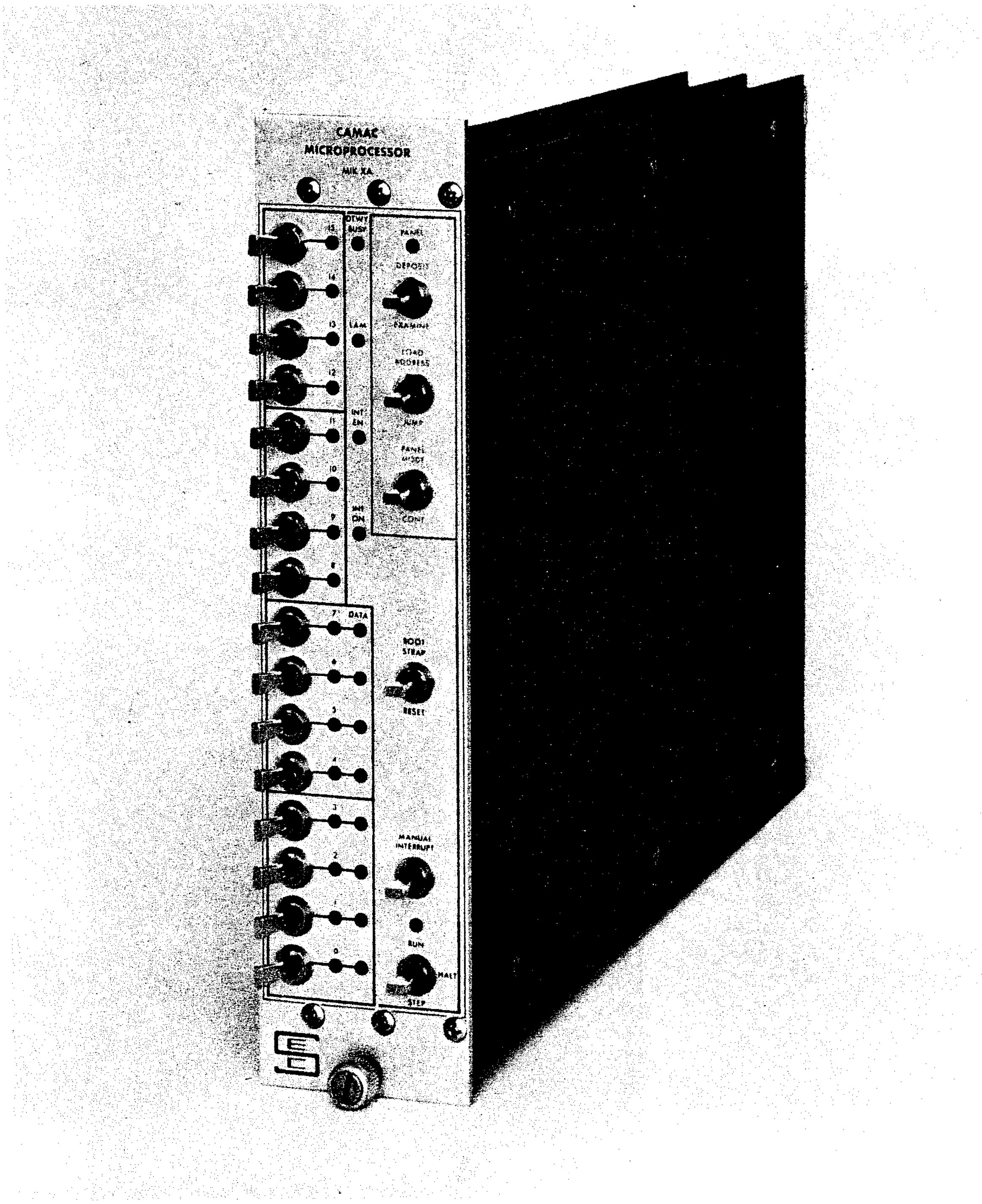

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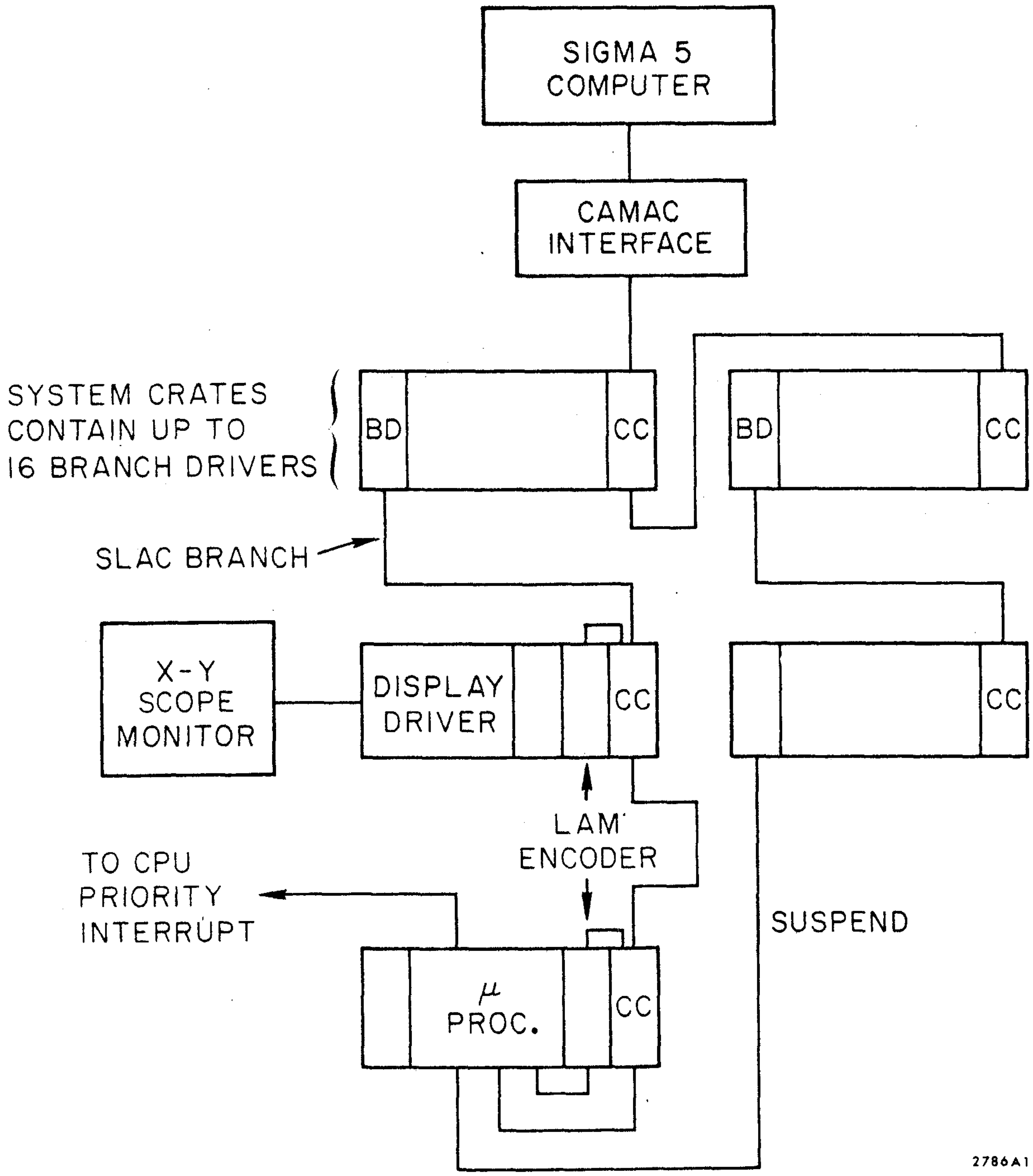
Fig. 2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MONITOR
DISPLAY
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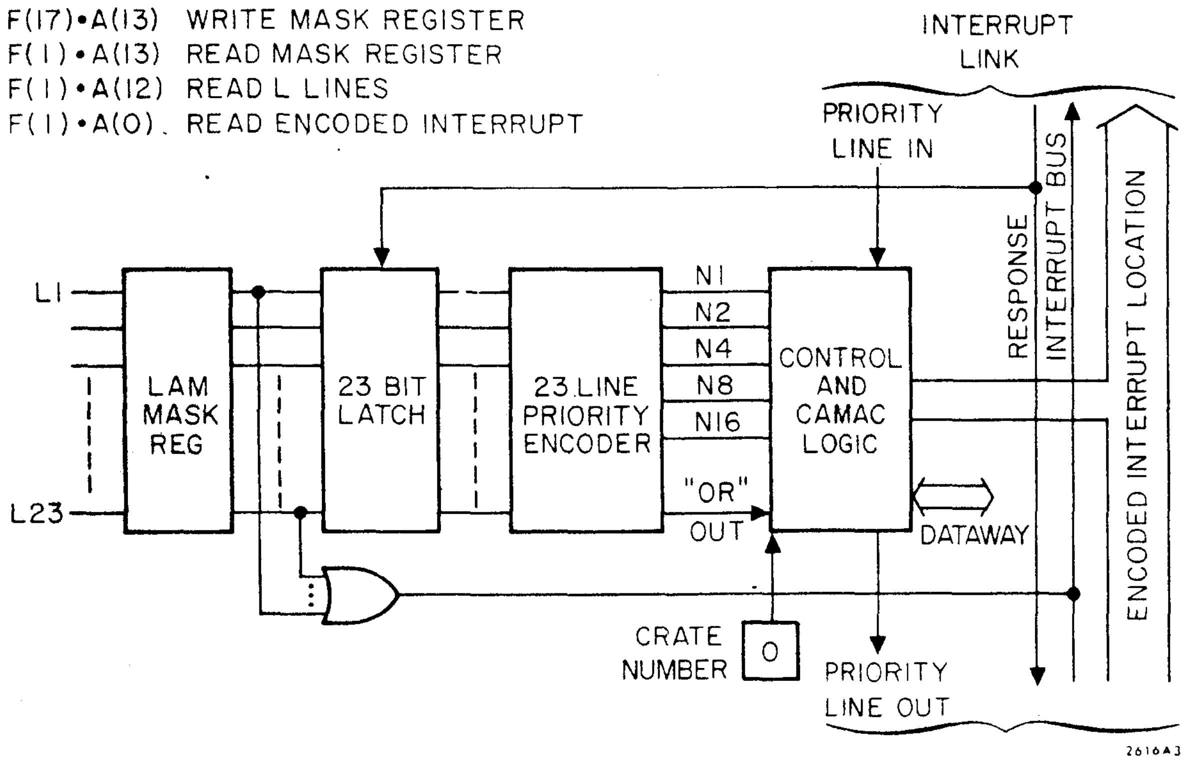
Fig. 3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INTERRUPT LINK
PRIORITY LINE IN
RESPONSE
INTERRUPT BUS
ENCODED INTERRUPT LOCATION
L1
L23
LAM MASK REG
23 BIT LATCH
23 LINE PRIORITY ENCODER
N1
N2
N4
N8
N16
"OR" OUT
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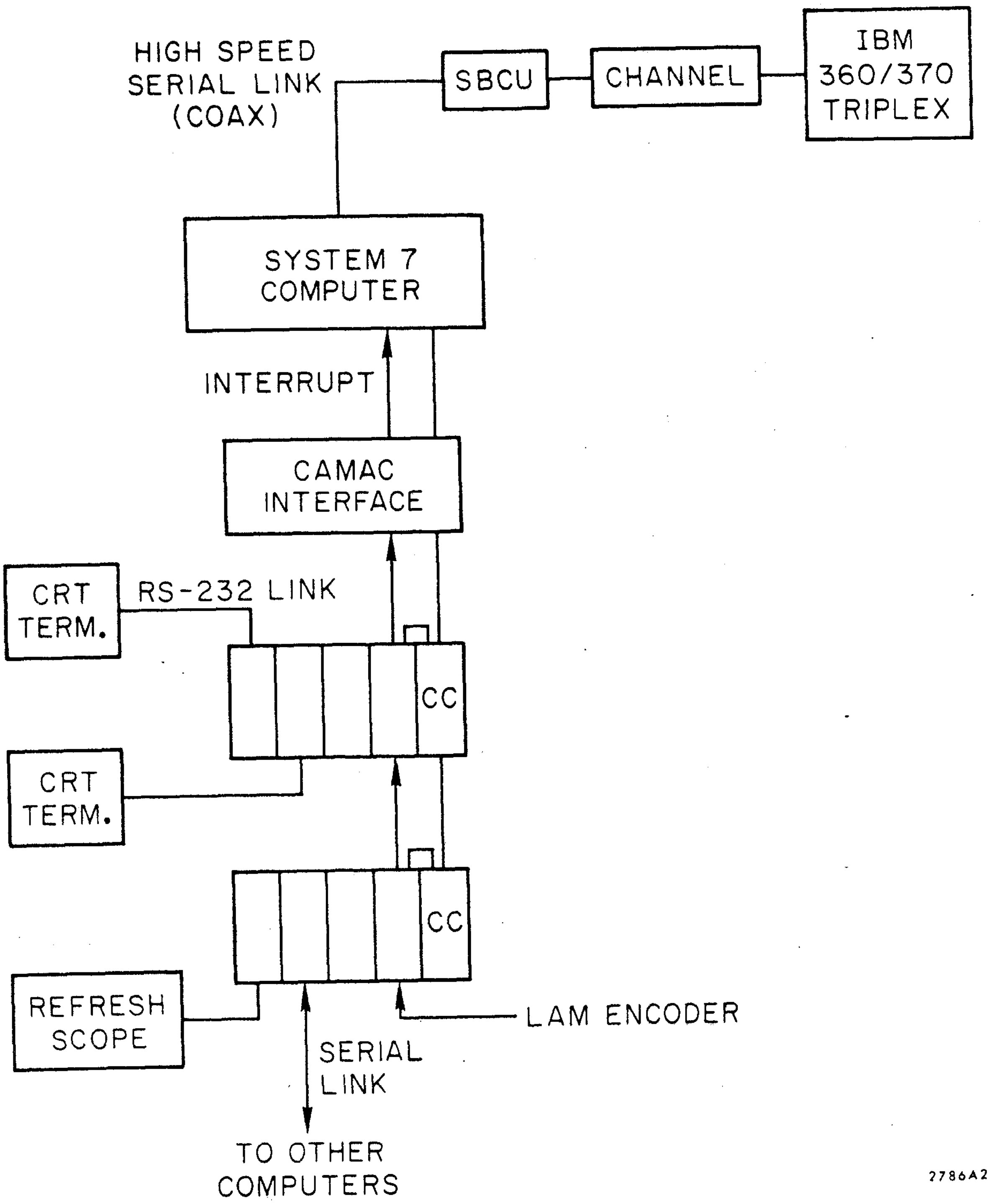
DATAWAY
CRATE NUMBER
0
PRIORITY LINE OUT
2616A3

Fig. 4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RS-232 LINK
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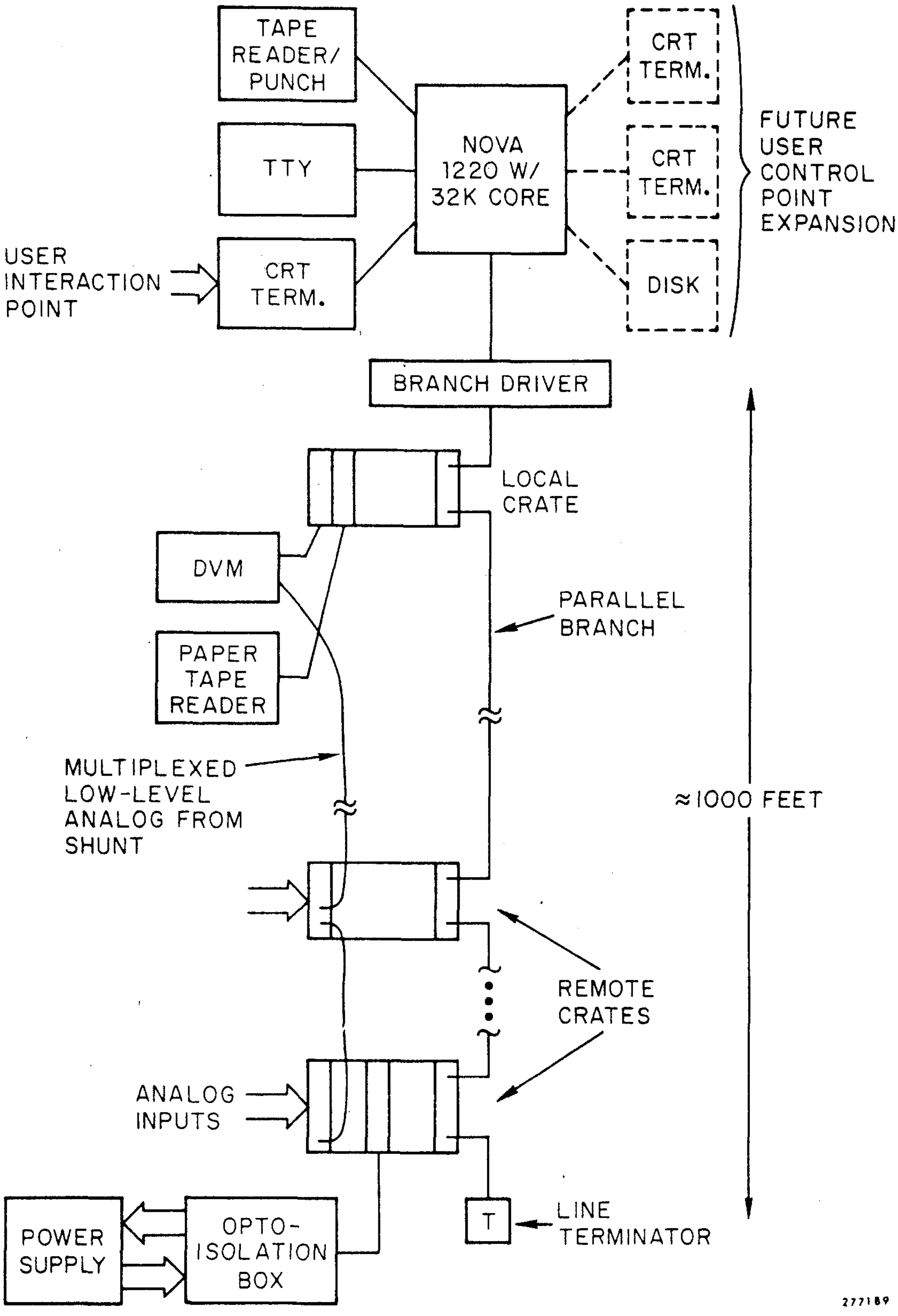
Fig. 5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BRANCH DRIVER
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DVM
PAPER TAPE READER
PARALLEL BRANCH
MULTIPLEXED LOW-LEVEL ANALOG FROM SHUNT
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Fig. 6

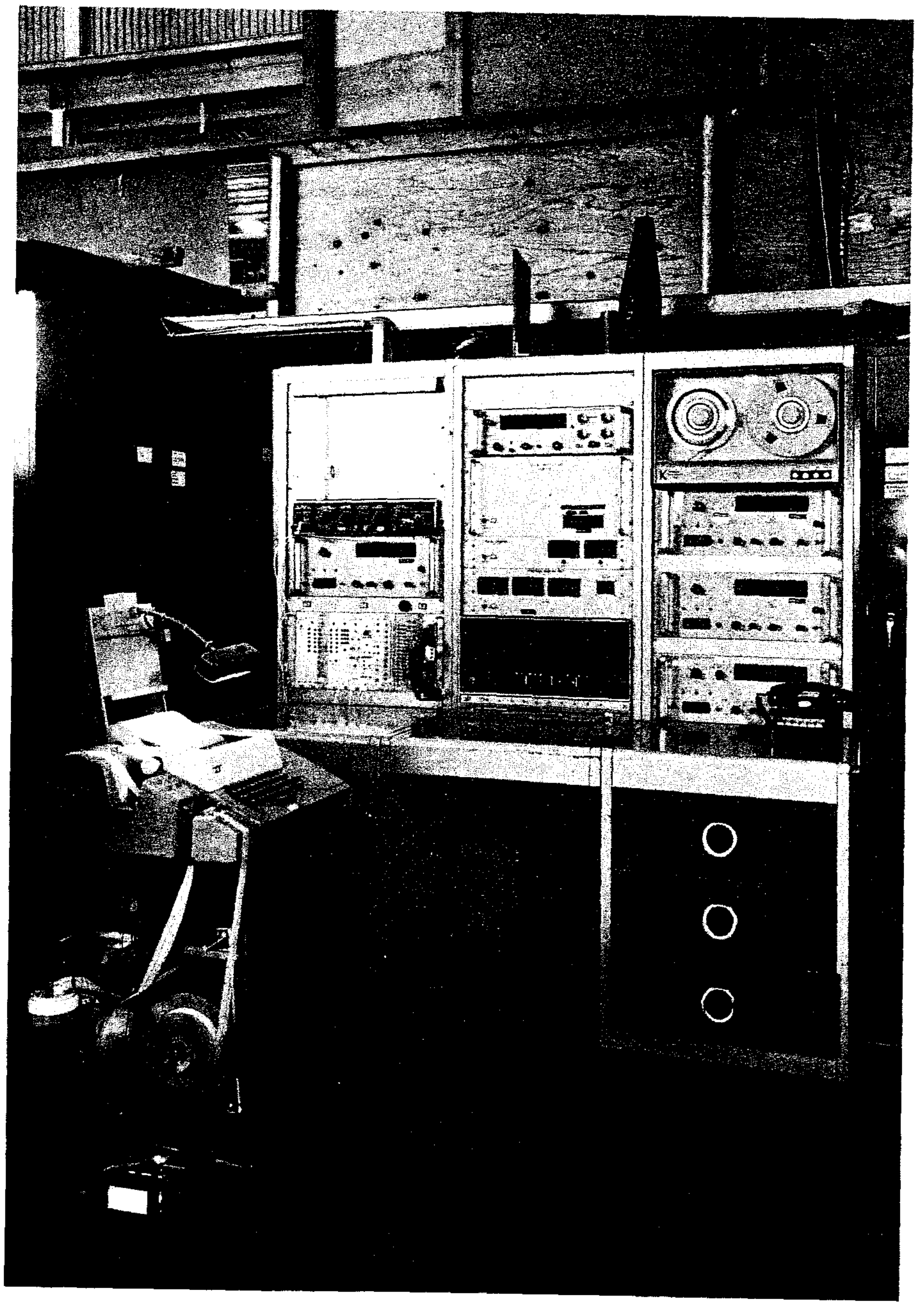

Fig. 7