

IMPLEMENTATION AND OPERATION OF A VAX-BASED DATA ACQUISITION SYSTEM FOR THE LARGE COIL TASK*

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Abstract: The VAX-based data acquisition system for the International Fusion Superconducting Magnet Test Facility (IFSMTF) at Oak Ridge National Laboratory (ORNL) is a second generation system that evolved from a PDP-11/60-based system used in the two-coil test and facility shakedown. The VAX 11/780 processor has been interfaced through a CAMAC fiber-optic byte serial highway to five existing LSI-11/23 frontend processors through dataway access port (DAP) modules. The VAX CAMAC interface has permitted the addition of analog input channels for the refrigeration system and analog and digital outputs to drive display devices. Software utilities are provided to operate the data acquisition hardware, maintain data base files, and display data. Graphical display of data is accomplished through the use of VAX IDL (Interactive Data Language), which provides device-independent data presentation. Output from IDL is available for Tektronix displays and has been extended to generate TKF and Versaplot graphics metafiles for hardcopy output to Versatec printer/plotters. In addition, a Sension display system is available for graphical display of real-time data in the form of strip chart and tabular displays. This paper describes the hardware and software design of the system and the operation of the system during the full-array testing sequence.

1. Introduction

The Large Coil Program (LCP) at ORNL is an international collaboration to test large prototype superconducting toroidal field coils. Six coils are being tested in a compact toroidal array in a cryogenic test facility known as the International Fusion Superconducting Magnet Test Facility (IFSMTF). Three of the coils were provided by U.S. industrial participants under the direction of the LCP at ORNL. The three remaining coils were designed and built by Euratom, Japan, and Switzerland. Each of the six coils is of a different design and construction. The testing is being done to analyze the designs of the coils and guide future design improvement:

Each coil has approximately 300 diagnostic sensors that measure parameters such as temperature, strain, voltage, current, pressure, displacement, and flow. The test facility has 800 temperature and strain sensors that require monitoring. In addition, the helium refrigerator system has 90 temperature, pressure, and flow sensors to be monitored.

An initial partial-array test was performed in 1984 for the purpose of shaking down the facility. The data acquisition system during this test was based on a PDP-11/60 computer and has been described by Gould [1]. Since the partial-array test, the system has been upgraded with a VAX 11/780 and now supports real-time data access and analysis as well as enhanced graphical output.

2. System Configuration

The data acquisition system for the LCP (LCPDAS) has been developed to acquire, store, analyze, and display data acquired from the IFSMTF. A block diagram of the LCPDAS is shown in Fig. 1. All data from the experiment are acquired from four independent frontend systems, each of which has a specific function. The VAX 11/780 is the central processor of the system and is part of a VAX

cluster in the Fusion Energy Division of ORNL. The VAX cluster enables all of the VAXes on the cluster to have access through the STAR coupler to the cluster-wide data storage resources. The data acquired from the LCP are being stored on a single RAB1 (456-megabyte) disk. The VAX is interfaced to the four frontend systems through an 800-m fiber-optic CAMAC serial highway that runs at 5 MHz.

Users are able to access the system through VT100-compatible terminals with built-in Tektronix 4010 emulation. Two Sension graphical display systems are also available that allow users to display real-time simulated strip charts and tabular displays. The Sension systems are driven from the CAMAC dataway, enabling high-resolution real-time displays. A Versatec V80 printer/plotter, which is interfaced to the VAX through fiber-optic modems, is available to users in the IFSMTF control room for hardcopy output.

2.1. Frontends

The four frontend systems used in the LCPDAS are identified as the fast frontend (FFE), slow frontend (SFE), facility frontend (FAC), and refrigerator frontend (REF). The FFE is designed to provide millisecond sampling rates during transient events (coil quenches and heater tests) and 1-s sampling rates during normal operation. The primary signals monitored by the FFE are voltage taps, heater signals, and thin film thermometers. The SFE is used for signals that need to be sampled on the order of every 5 s and may also scan a limited number of channels during a transient event. Typically, coil temperature, strain, and flow signals are interfaced to the SFE. The FAC is a slow-scanning system for monitoring the facility temperature and strain. The REF, added since the partial-array test, monitors the helium refrigerator operation.

2.1.1. Fast Frontend: The FFE is a combination of four LSI-11/23 systems, each with DMA access to 64 channels from an ADAC 1000 series A/D converter. The FFEs interface to the VAX through Standard Engineering DAP-11 CAMAC modules that provide DMA transfer from the CAMAC dataway to the LSI-11 Q-bus. The FFE systems run a stand-alone application program written in PDP-11 MACRO-11 assembly language [2, 3] that is assembled on the VAX and downloaded to the LSI-11. The DAP module provides access to the Q-BUS halt and power-up lines so that it is possible to halt the LSI-11 processor, download the FFE image, and start the FFE application task, all from the VAX. Terminal lines are run to each of the FFE LSIs for debugging purposes.

2.1.2. Slow Frontend: The SFE is also an LSI-11/23 system with an Analogic 5400 A/D converter system with 512 channels. The Analogic system uses DMA to transfer the data it collects to the LSI memory. The SFE runs an RSX-11/S image that is downloaded from the VAX through a DAP-11 CAMAC module. The RSX-11/S image is created on the VAX and consists of tasks written in FORTRAN. A terminal is interfaced to the SFE to allow monitoring of its operation and calibration of Analogic channels.

2.1.3. Facility Frontend: The FAC is an FX Systems 2000 scanner with 800 channels. This system is capable of scanning all 800 channels in 3 min and uses an RS-232 interface to transfer data to the VAX through a CAMAC RS-232 module. A local terminal is used for local operation, display, and calibration functions.

2.1.4. Refrigerator Frontend: The REF is a logical frontend of three Lecroy 8252 scanning ADC CAMAC modules. Each module

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MASTER

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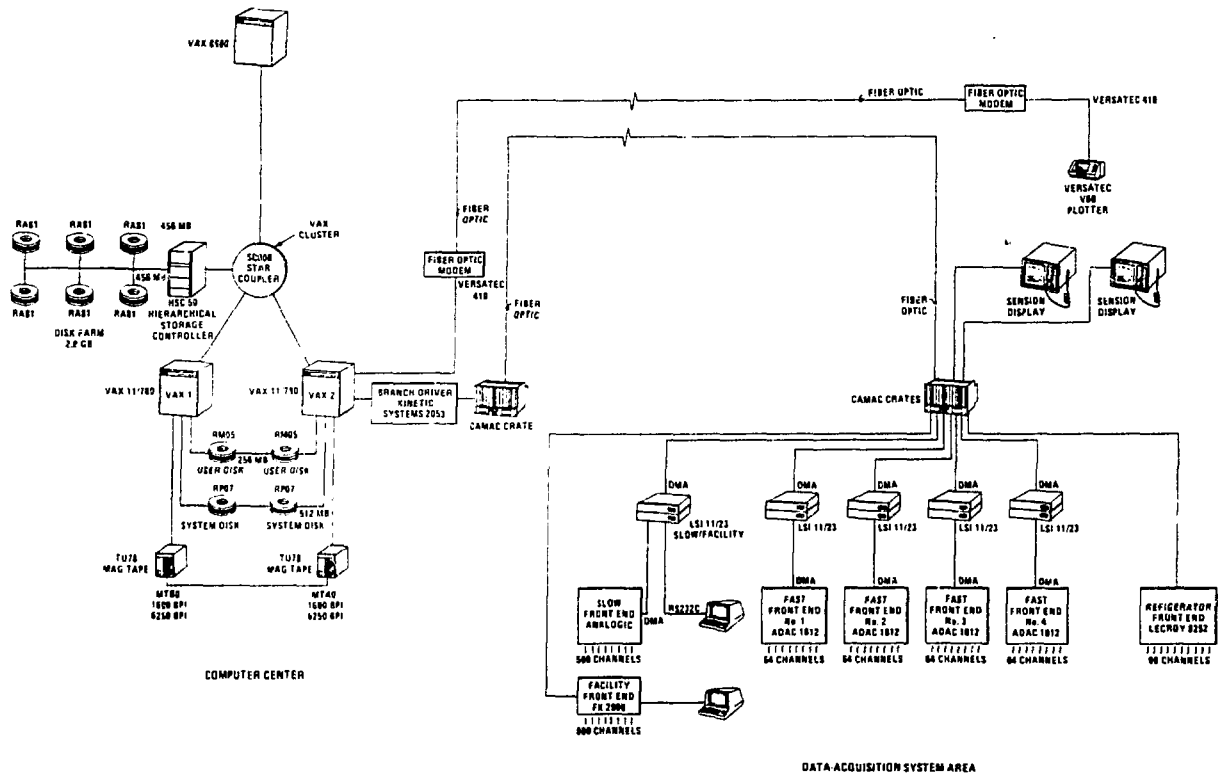


Fig. 1. LCPDAS configuration.

is scanned individually from the VAX, but the data from the 96 channels are treated as though they came from an individual source. The number of CAMAC modules used by the REF can be easily extended at any time.

3. System Software

The system software is designed with documentation and maintainability in mind and is written primarily in VAX-11 PASCAL. To increase programming efficiency and to provide software documentation, VAX-11 Module Management System (MMS) has been used throughout the software development. Software utilities are provided for operating the data acquisition hardware, maintaining data base files, displaying real-time data, and plotting analyzed data.

3.1. Data Base Architecture

Several data bases have been used in the LCPDAS to enable correlation of sensors with channels and to convert the raw sensor data into meaningful physical units. A sensor assignment file (SAF) is used to define information for all of the coil and facility sensors. For sensors that require a nonlinear conversion to physical units, there is an intrinsic calibration file (ICF) that defines the algorithm used to convert the sensor output. Each frontend has associated with it a channel assignment file (CAF) that defines the sensor-to-channel mapping, a parameter file (PAR) that defines the frontend operating characteristics, and a calculation channel file (CAC) that defines the multiple sensors from the CAF that are used together to determine physical parameters such as helium flow. Because there are more sensors than channels, there is frequent patching of sensors to channels, which requires multiple CAFs and CACs for each

frontend. In order to keep the active data base files organized, a test configuration file (TCF) is used to define the active CAF, CAC, and PAR for each frontend at a particular time. The test configuration is then stored with the raw data to enable subsequent retrieval and conversion.

Each data base file system has a utility program associated with it to enable file maintenance. These utility programs are designed with screen-oriented features and on-line help for ease of use. In addition, each file structure has been defined in the VAX Common Data Dictionary, and Datatrive procedures have been implemented to enable sophisticated report generation.

3.2. Data Acquisition Architecture

The VAX-based data acquisition system for the LCPDAS utilizes a software architecture that provides a high level of data accessibility from the user's perspective and a high level of maintainability from the software perspective. This architecture utilizes a design approach that incorporates all of the generic data acquisition and operator interface functions into a collection of common utility routines. The frontend-dependent functions are implemented through a collection of so-called event action routines. Each category of frontend systems is supported by a VAX process running the generic data acquisition code with the appropriate frontend-specific event action routines. The data acquisition code is a queue-driven implementation in that various conditions give rise to events that are posted to an event queue for subsequent dispatching to one of the frontend-specific event service routines. The frontend-specific event dispatcher determines whether and how a particular event will be interpreted within the context of the frontend-specific requirements. The architecture readily accommodates the addition of new frontend

data sources. Three methods are supported for the disposition of data from the frontend source. These data sinks are:

- real-time global data section,
- scan data files, and
- transient event data files.

Each frontend source may send data to all or part of the supported sinks for data. The collection and storage of the data in the real-time global data sections are completely decoupled from the archiving of scan data, thereby making it possible to scan the frontend data source at a much higher rate than the archival rate. The architecture for a representative LCPDAS frontend system is depicted in Fig. 2.

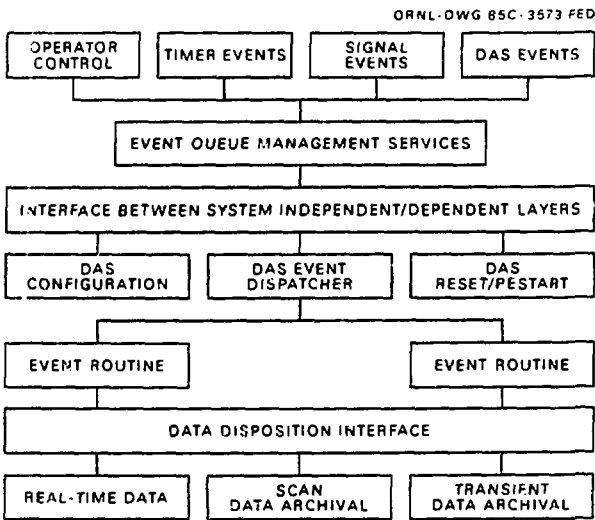


Fig. 2. Representative LCPDAS frontend system.

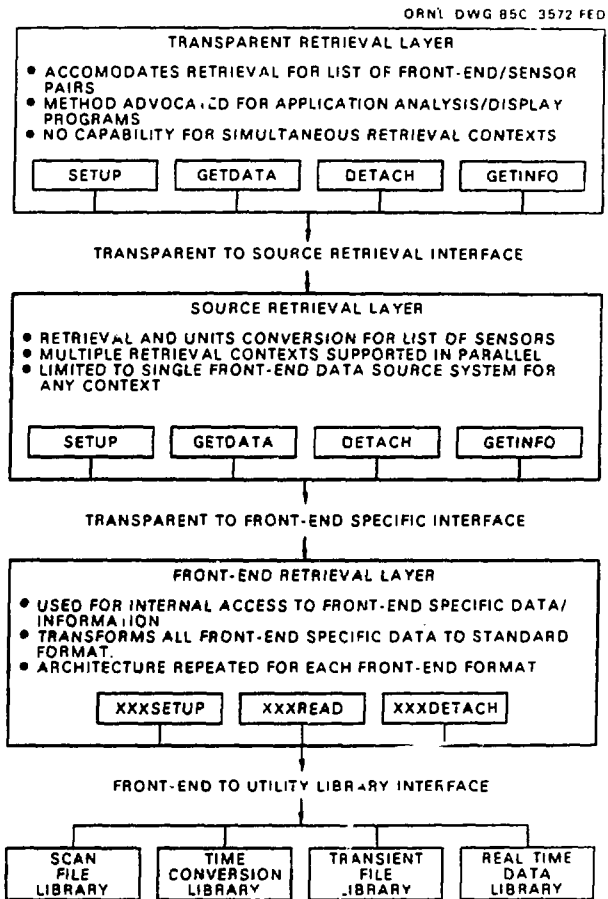


Fig. 3. Data retrieval software.

3.3. Data Retrieval Architecture

The VAX-based data retrieval system for the LCPDAS utilizes a software architecture that provides integrated access to the data acquired from any of the frontend data sources that make up the experimental data system. The data retrieval software is a layered implementation designed to isolate application programs from the inherent differences among frontend data systems and to decouple all such applications from the data sources so as to transparently accommodate the addition of other frontend systems in the future. A block diagram of the data retrieval software is shown in Fig. 3. The top two layers of the data retrieval software are supported for application interfacing, providing the so-called transparent and source-specific layers in the data management architecture. Access to data through each of these layers has its own advantages and disadvantages as described in the block diagram. Access to the lower layers of the data management architecture from applications is not supported but strongly discouraged because of compatibility issues in future releases of the software.

4. Graphics

Graphical display of data is accomplished through the use of VAX IDL, which provides device-independent data presentation. Output from IDL is available for Tektronix displays and has been extended to generate TKF and Versaplot graphics metafiles for hardcopy output to Versatec printer/plotters. This extension makes it possible to generate multipage plots of data in a strip chart fashion over long periods of time. A data metafile utility program

has been implemented to allow storage of retrieved data in a predefined format known as data metafiles. The data metafiles are then used for subsequent analysis and plotting. In addition, software for a Sension display system has been developed for graphical display of real-time data in the form of strip chart and tabular displays.

5. System Operation

The data acquisition processes in the LCPDAS system are controlled through a utility program known as DASOPER. This program allows any user to monitor the frontend system's current state. Users with sufficient privilege may start up, shut down, and modify scan and archival parameters of the frontend systems. System error messages and events are logged on a DECwriter console terminal in the IFSMTF control room.

Users of the LCPDAS interface with the system through VT100-compatible terminals that have Tektronix 4010 emulation capabilities. All of the utility programs for users employ the VT100 screen management software on the VAX to create user menus and data base displays. Several utilities have been developed for data display on users' terminals. A mimic display program has a pictorial display for each system in the facility and updates the data fields in the display periodically. An example of a mimic display is shown in Fig. 4.

The upgrade of the LCPDAS system from the PDP-11/60-based system to the VAX has made a dramatic improvement

WH STRUCTURE PRT DISPLAY (K)

ORNL-DWG 85-2609 FED

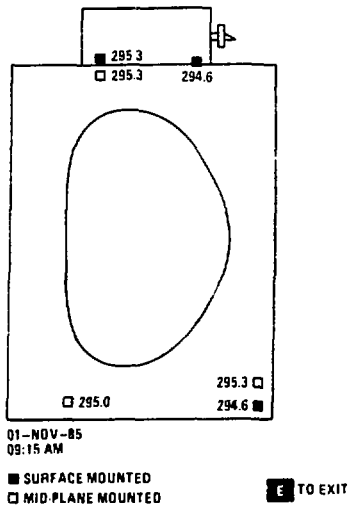


Fig. 4. Example of mimic display.

in the operability, reliability, and ease of use of the system. In addition to the obvious speed and accessibility enhancements provided by the VAX, the LCPDAS system has many functional improvements in the areas of real-time data display and graphical output.

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References

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