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Computer-Controlled Data Acquisition System for the ISX-B Neutral Injection System

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COMPUTER-CONTROLLED DATA ACQUISITION SYSTEM FOR THE ISX-B NEUTRAL INJECTION SYSTEM*

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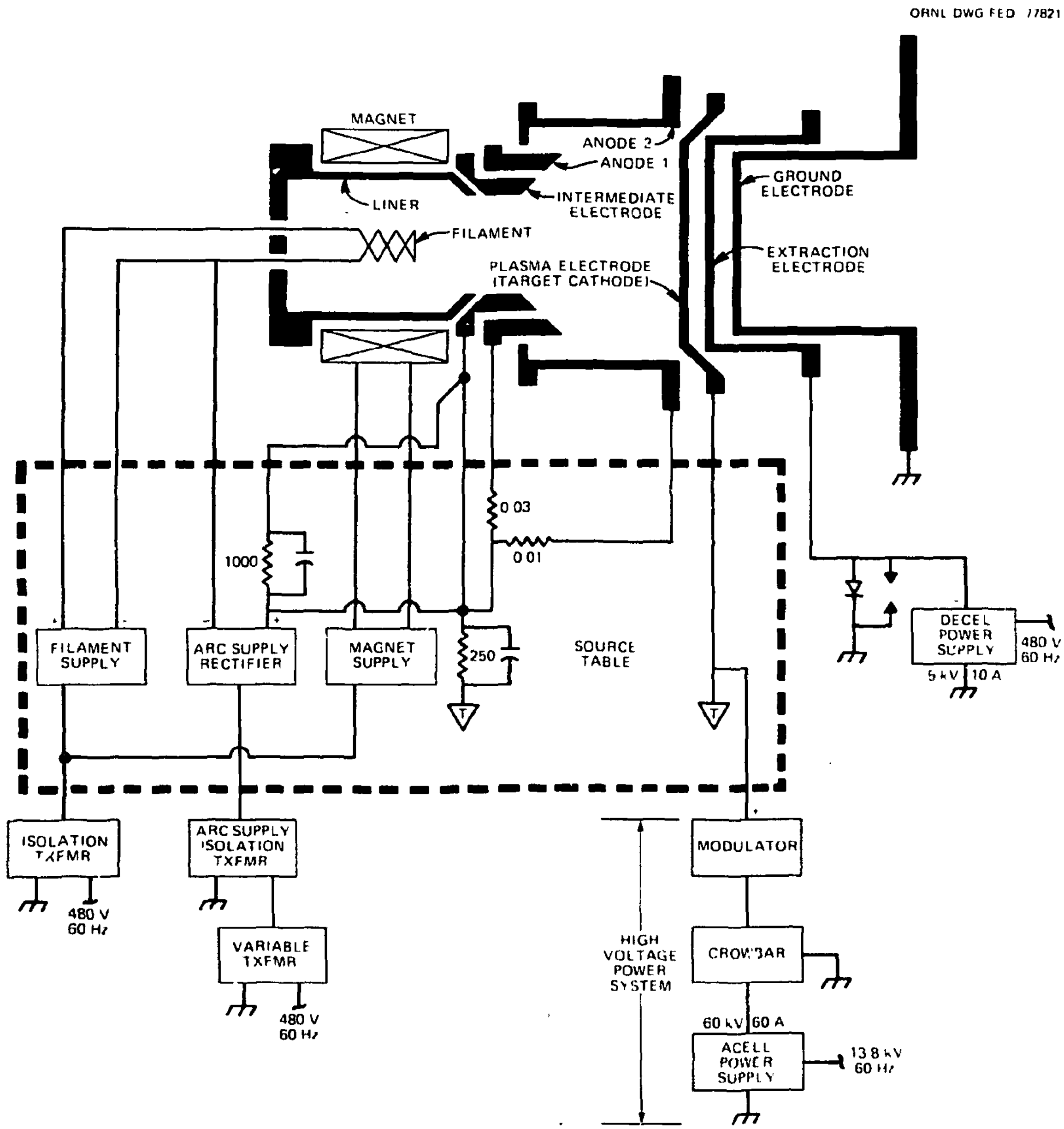
INTRODUCTION

The ISX-B tokamak experiments at Oak Ridge National Laboratory (ORNL) are directed primarily toward investigating high-beta plasmas.[1] A fundamental part of these experiments is the neutral beam injection system,[2] which supplies additional ion heating to the plasma.

The ORNL beam line duoPIGatron ion source[3] is shown in Fig. 1. Hydrogen ions are generated in the arc chamber and accelerated between the plasma electrode and the ground electrode. The ions are neutralized in a hydrogen gas cell and then pass into the tokamak, where they reionize and thermalize, depositing their energy in the background plasma. Proper control of the source parameters is necessary to maximize the extracted beam power and to optimize the beam optics. The prerequisite for this type of source control is a data acquisition system with immediate display. In response to this need, a data acquisition system was developed to monitor selected beam parameters and display the results in a usable form. The important parameters include extracted ion current, accelerating voltage, arc currents and voltages, and hydrogen gas input.

1. DESIGN REQUIREMENTS

To provide the information needed for proper source control, a data acquisition system must monitor the important parameters, integrate the data over a selected interval to remove noise, and display the results immediately for use by the beam line operators. The prototype system described below processes eight channels of data (expansion is trivial)



TYPICAL ION SOURCE
ELECTRICAL POWER SYSTEMS

Fig. 1.

for pulse lengths of typically 100 ms. Sampling rates of about 500 Hz are required. The source parameters under analysis originate at the source table, which is a large metal enclosed box containing the power supplies and controls for the ion source. The source table is at the acceleration voltage, which is typically 50 kV above ground. It is desirable to be able to display the data of each pulse immediately after the pulse in the interval before the next pulse; this interval is typically 10 s.

A particular problem with these measurements is the very high noise level. During operation the source generates large amounts of rf noise and, in a fault flashover to ground, can produce multi-kV transients in all the circuitry.

The ISX-B data acquisition system is based on CAMAC protocol, because CAMAC is designed to work in a high-noise industrial environment. The system was designed to display the results on a terminal at ground potential; this allows stand-alone operation. A necessary requirement was that the communications link be capable of interfacing with a central control computer.

2. SYSTEM DESCRIPTION

A. Hardware

CAMAC hardware and CAMAC standard modules were used where possible. The advantages of this route are the ready availability of components and the standardization of the system protocol. A commercially available LSI-11 microcomputer, the MIK-11/2,[4] was used as the crate controller; it also supplied data manipulation capabilities. The MIK-11/2 has both a volatile random-access memory (RAM) and a permanent (non-volatile) memory as required for the storage of system startup and operating systems. Bubble magnetic memory devices[5] were chosen over a disk system because of the disk's susceptibility to poor environmental conditions. The bubble memories are software-configured to operate like a disk system and provide all the necessary requirements, but they have no moving parts.

A typical data channel is shown in Fig. 2. At the beginning of a beam pulse, a start trigger enters through an isolation amplifier[6] to an analog-to-digital converter (ADC)[7] and clock.[8] This trigger pulse starts the ADC digitizing at the rate determined by the clock. The ADC performs conversions at the set rate until its memory is full, at which time it generates a "look at me" (LAM) signal to inform the microcomputer that the conversions are complete. The MIK-11/2 recognizes this condition and stops the ADC and the clock. The ADC memory is then copied into RAM, and data processing begins. The results are displayed via an optical link on a video display and a hard-copy printer.

B. Software

The software (Fig. 3) is written in LSI-11 assembler language in modular form and operates in two basic loops, one to handle the CAMAC system and the other to handle data manipulation. Once turned on, the system programs are booted into RAM from the bubble memory. The CAMAC control loop assigns constants, sets pointers, enables the CAMAC units,

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SOFTWARE FLOW DIAGRAM

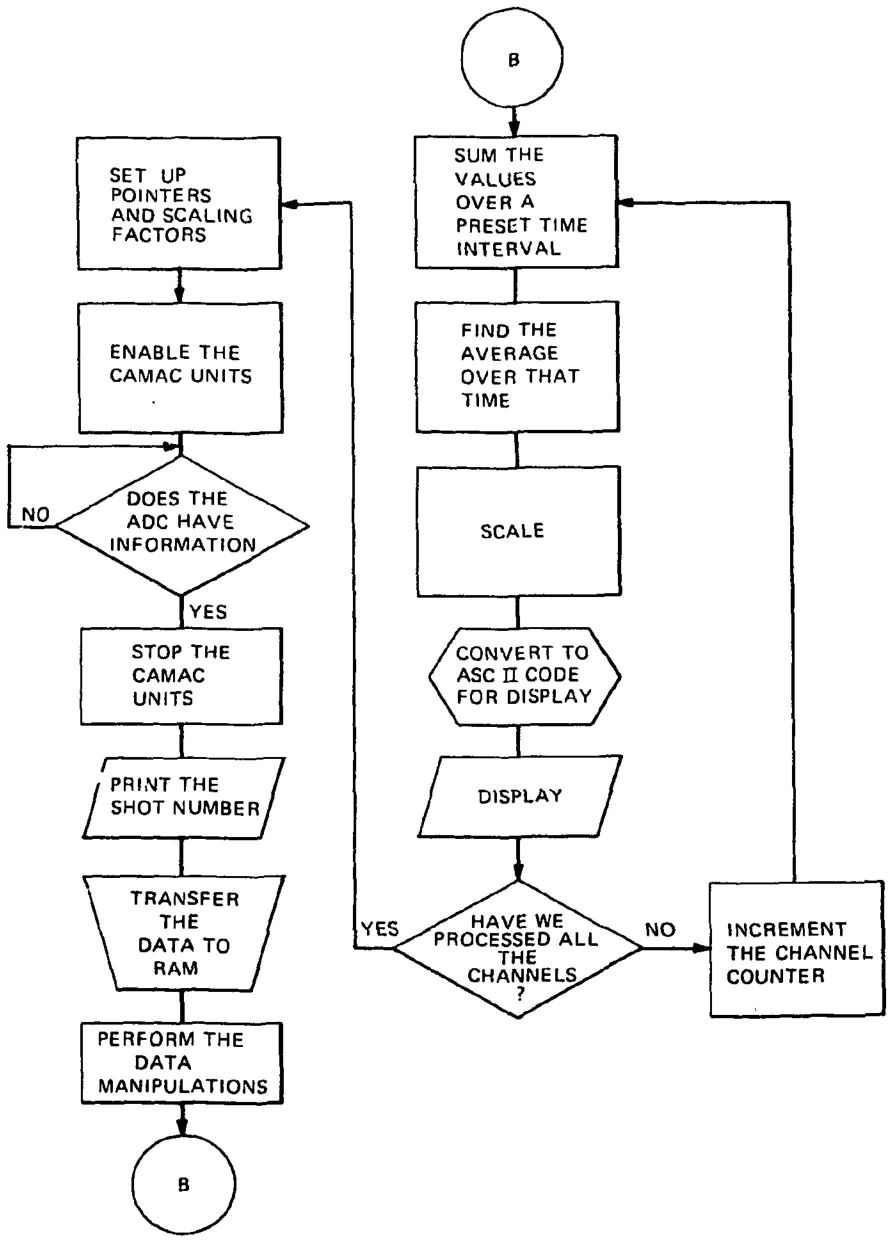

Fig. 2.

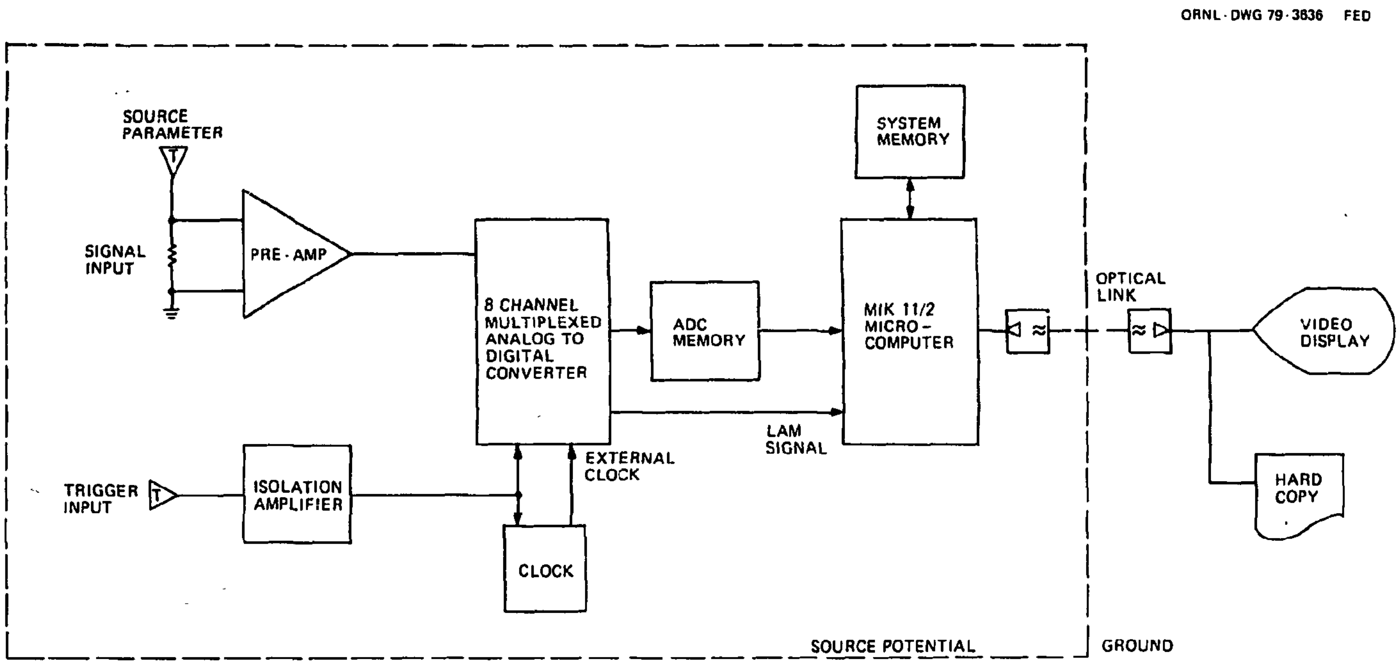
ORNL-DWG 79-3636 FED
SOURCE PARAMETER
SIGNAL INPUT
PRE-AMP
8 CHANNEL MULTIPLEXED ANALOG TO DIGITAL CONVERTER
ADC MEMORY
SYSTEM MEMORY
MIK 11/2 MICRO-COMPUTER
LAM SIGNAL
EXTERNAL CLOCK
TRIGGER INPUT
ISOLATION AMPLIFIER
CLOCK
OPTICAL LINK
VIDEO DISPLAY
HARD COPY
SOURCE POTENTIAL
GROUND

Fig. 3.

and waits for a LAM. Upon receiving the LAM the program stops the CAMAC units, transfers the data to RAM, and prints the shot number for bookkeeping purposes. Control is then passed to the data manipulation loop, which is executed once for each input channel of data. Since the ADC digitizes more data than are relevant, a certain time range must be selected and the data must be integrated over this period. The resulting average value is then scaled to its appropriate range, converted to the terminal display code, and transmitted over the optical link to the display devices. After data processing, system control is transferred back to the CAMAC control loop, and it waits for the next beam pulse.

3. OPERATING EXPERIENCE

The data acquisition system underwent two test cycles on an ISX-B beam line. The first cycle was terminated when an electrical fault inside the source cabinet generated large noise pulses that damaged the CAMAC ADC module. The problem was attributed to the noise entering on an unprotected trigger input, and the isolation amplifier was installed.[6] Frequent intermittent problems were experienced with the bubble memory system on startup, but the system could be brought on line after several system program load requests (boots). It is not known whether this is a fault in the initialization procedures or a hardware problem in the bubble controller, but we suspect the latter.

No problems were experienced in the second test cycle, which included a number of sparkdowns of the high voltage power supply; this suggests that the noise immunity of the system is now satisfactory. We do not have enough experience to evaluate the practicality of running computer-controlled CAMAC in a frequent power on-off operating cycle; however, the prototype was cycled several hundred times with no problems.

The important result is that the very attractive concept of operating a computer-controlled data acquisition system in the remote and hostile environment of the source table appears practical.

4. FUTURE IMPROVEMENTS

Currently the data manipulation routines are being rewritten in FORTRAN to improve the flexibility and scope of their functions. The FORTRAN programs will be developed on a higher level computer and down-line loaded into the MIK-11/2, where they can be transferred to bubble memory and permanently stored.

The long-range plan is to implement the system on both ISX-B beam lines, to replace the terminal at ground potential with a more advanced computer to permit data archiving, and to develop the necessary programs to permit operation of the beam sources through computer control.

5. CONCLUSION

A CAMAC-based computer-controlled data acquisition system was operated at a neutral beam source potential despite the high-noise environment. This facilitates access to beam line data and opens new options for diagnostics and control.

ACKNOWLEDGMENTS

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[1]M. J. Saltmarsh, presented at the 26th National Symposium of the American Vacuum Society, New York, October 2-5, 1979; proceedings to be published in J. Vac. Sci. Technol.

[2]L. A. Massengill, P. H. Edmonds, S. C. Bates, and C. M. Loring, presented at the 8th Symposium on Engineering Problems of Fusion Research, San Francisco, California, November 1979; proceedings to be published.

[3]M. M. Menon, G. C. Barber, C. W. Blue, W. K. Dagenhart, R. C. Davis, C. A. Foster, W. L. Gardner, H. H. Haselton, J. Kim, S. L. Milora, R. E. Potter, P. M. Ryan, D. E. Schechter, S. W. Schwenterly, D. O. Sparks, W. L. Stirling, C. C. Tsai, J. H. Whealton, and R. E. Wright, Oak Ridge National Laboratory Report ORNL/TM-6658 (1979).

[4]The MIK-11/2 microcomputer is manufactured by Standard Engineering Corp., 44800 Industrial Dr., Fremont, California 94538.

[5]The MBC-11/MBB-11 BUBBL-MACHINE is manufactured by BUBBL-TEC Division of PC/M, Inc., San Ramon, California.

[6]The Logic Isolator is manufactured by Jorway Corp., 27 Bond St., Westbury, New York 11590.

[7]The Transient Recorder TR-810 is manufactured by Standard Engineering Corp., 44800 Industrial Dr., Fremont, California 94538.

[8]The Model 217 Gated Clock Generator and Model 220 Eight-Channel Delay Generator are manufactured by Jorway Corp., 27 Bond St., Westbury, New York 11590.