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OAK RIDGE NATIONAL LABORATORY
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ABSTRACT

The Medium Power Neutral Beam Test Facility at Oak Ridge National Laboratory was constructed in order to develop, test, and condition powerful neutral beam lines for the Princeton Large Torus experiment at Princeton Plasma Physics Laboratory. The data acquisition system for the test stand monitors source performance, beam characteristics, and power deposition profiles to determine if the beam line is operating up to its design specifications. The speed of the computer system is utilized to provide near-real-time analysis of experimental data. Analysis of the data is presented as numerical tabulation and graphic display.

INTRODUCTION

The data acquisition system of the Medium Power Neutral Beam Test Facility has two important functions. Data from the water-cooled calorimeters are measured, recorded, and used to deduce the quality of beam focusing and the output power of the neutral beam source. The source data, acquired from the beam test stand, contain values of source currents, pressures, and voltages.

Calorimeter data, which change slowly, are taken continuously except when the beam is on (when noise generated by the source causes interference). Source data are taken only when the beam is on.

DATA ACQUISITION HARDWARE

The main processor is a PDP-11/40[1] with a floating point instruction set and 64K words of core memory. Peripheral devices consist of dual RK05 disk drives, dual DEC-tape drives, a Versatec line printer/plotter, a VT-11 graphic display, and a DECwriter-II. Interprocessor communications with the local Magnetic Fusion Energy Network (MFENET) DECsystem-10 computer are provided by a serial asynchronous interface which meets Electronic Industries Association (EIA) standards.

Attached to the PDP-11 UNIBUS is a BI-RA Systems[2] microprogrammable branch driver (MBD) with 4K words of solid-state memory. This 16-bit microprocessor has an add time of 350 ns and a store time of 50 ns. The MBD can do direct memory access on the PDP-11; however, to the PDP-11 it looks like any other direct memory access peripheral device.

Data are obtained using a computer automated measurement and control (CAMAC)[3] system in conjunction with the MBD. CAMAC equipment consists of the following modules: a 64-channel, 12-bit analog-to-digital converter (ADC); five 6-channel scalar modules; a flag sense module; two programmable real-time clock modules; and a trigger module. Figure 1 is a diagram of the data acquisition system.

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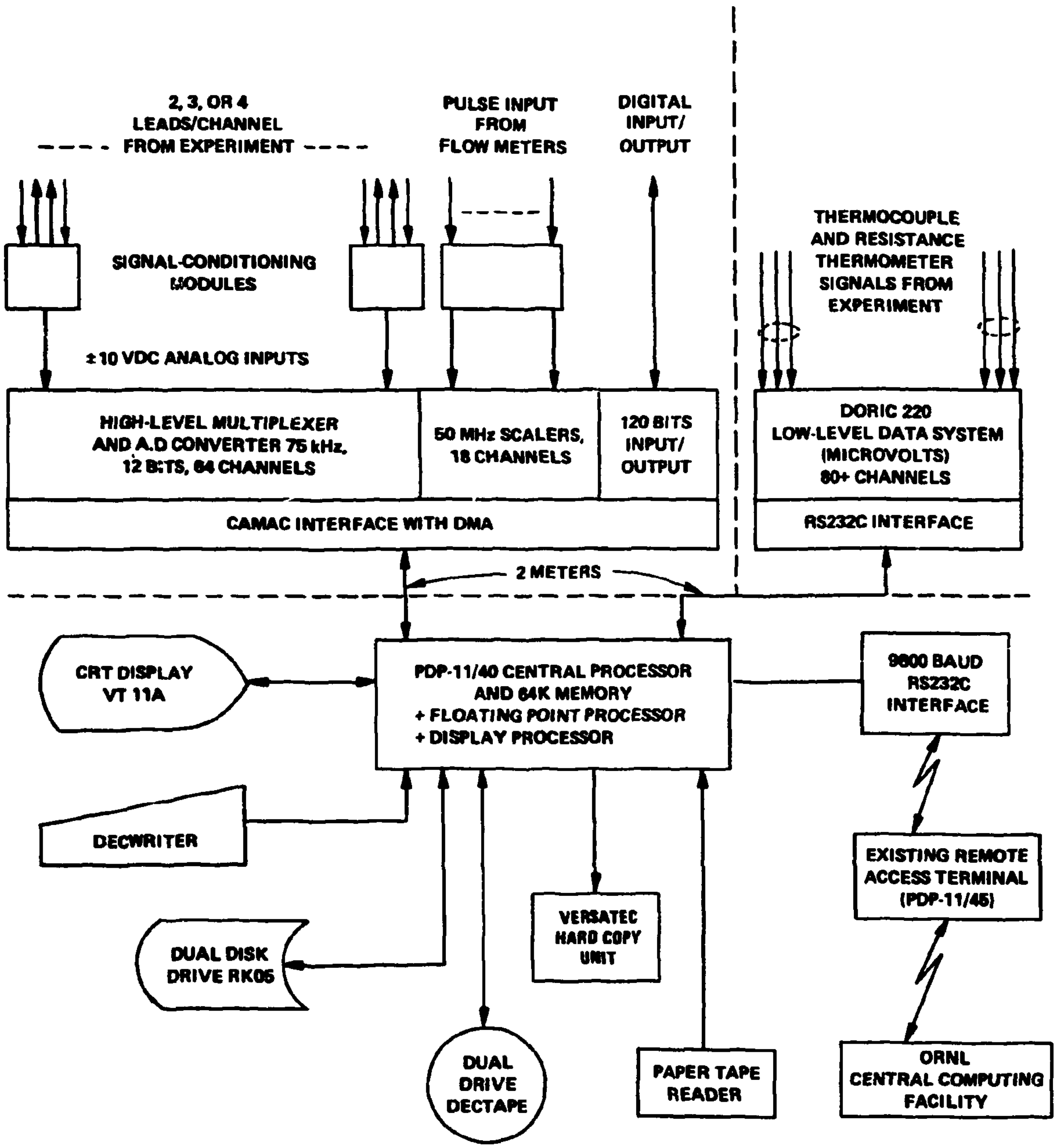

Fig. 1. Block diagram of the interactive data acquisition system for neutral beam development.

DATA ACQUISITION SOFTWARE

The MBD's data acquisition routines are put into its memory by the host PDP-11 prior to the start of data acquisition. Once data acquisition is begun, the MBD runs independently of the PDP-11 except for a 3-state flag in PDP-11 memory. If this flag is negative, it tells the MBD to halt; if zero, it means the MBD can transfer another shot into PDP-11 memory; and if positive, it means the PDP-11 has not processed the last shot stored in its memory. When the MBD cannot store its data in PDP-11 memory before the beam is scheduled to fire again, the data are lost.

Timing synchronization with the experiment is obtained in one of two ways. With the first method, an external clock mounted in the experiment control panel can be set to issue a trigger pulse which is detected by the flag sense module in the CAMAC crate. This in turn is detected by the MBD program, which then starts taking data. With the second method, a trigger pulse is sent to the experiment's control panel from the trigger module in the CAMAC crate. Acceptance of the pulse is detected in the same manner as above. A switch on the experiment's control panel can inhibit the trigger pulse if operator intervention is desired.

When the MBD sees a trigger pulse, it enters a data acquisition loop which takes eight channels of ADC input at a time interval of 1 ms between points on each individual channel for a total of 400 ms. This time is controlled by one of the clock modules. These eight channels give the pulse waveform of the currents, voltages, and pressures in the source.

After the "fast" or transient data points are recorded, the program goes to a second loop to obtain the collected power from the beam. The power data are obtained by measurement of changes in water temperature in the targets as indicated by low level signal thermopiles and amplification of these signals. A running sum of these digitized values and the number of samples in the sum is maintained by the MBD. Water flow is measured by scalar modules which count pulses from calibrated turbine meters. All resultant data contained in the MBD are transferred to the PDP-11 on a cycle-stealing basis.

DATA CALCULATION AND OUTPUT

Raw data are background corrected and converted to engineering units using calibration constants stored in a lookup table. Energy absorbed by each calorimeter, in kilojoules, is calculated by multiplying the water flow for each calorimeter by the average water temperature rise and then multiplying this by a constant. From these energies the power dissipated by each calorimeter in kilowatts and the percentage contribution to the total collected power are calculated. Results are then output in tabular form using the Versatec line printer/plotter. An example of the line printer output can be seen in Fig. 2. Calculated data can also be displayed on the VT-11 graphic terminal.

Another feature of the program is the use of the PDP-11 console switches for various functions. Switches are used to stop data acquisition, to suspend data acquisition, to request the program to accept new parameters, and to control what type of data is being displayed. Displayed data will either be tabulated power distribution data or waveform data from the source section of the experiment. When waveform data from the source are being displayed, the experimenter uses the light pen to pick which waveform is to be displayed. The program will then display that waveform until a new waveform is picked. An example of graphical display is shown in Fig. 3.

PERMANENT DATA STORAGE

The PDP-11 program provides the capability of storing data on disk for each shot, and will generate a unique 9-character name for each shot fired until 1987. A hardware link with the local MFENET DECsystem-10 computer exists. Acquired data will be stored temporarily on a local disk and transmitted from there through the PDP-11/45 communications coordination computer to DECsystem-10 disk memory, where another program will move the data from disk to magnetic tape permanent storage.

16-AUG-77 SPECIES MEASUREMENT

TIME 16:26:14

SHOT	28521		ENERGY/KJOULES	POWER/KWATTS	%THIS SHOT
1	ACCL	GRID	0.55	5.52	0.309
2	TRGT	CATH	3.26	32.56	1.823
3	GRND	GRID	2.73	27.34	1.531
4	AUX	GAS	2.15	21.47	1.202
5	GAS	CELA	9.17	91.67	5.133
6	GAS	CELB	6.61	66.14	3.704
7	HION	DUMP	52.71	527.14	29.518
8	MION	DUMP	12.95	129.49	7.251
9	LION	DUMP	4.83	48.32	2.706
10	BOTM	DPLT	3.18	31.83	1.783
11	TOP	DPLT	2.49	24.90	1.394
12	LEFT	DPLT	1.34	13.42	0.752
13	RHTE	DPLT	0.97	9.70	0.543
14	TOP	CAL	6.24	62.43	3.496
15	BOTM	CAL	5.09	50.93	2.852
16	ST	TRGT	0.00	0.00	0.000
17	INRT	TRGT	50.58	505.80	28.323
18	PLT	APTR	13.72	137.15	7.680

TOTAL ENERGY 178.382 TOTAL POWER 1783.822 SAMPLES1376

Fig. 2. Example of line printer output.

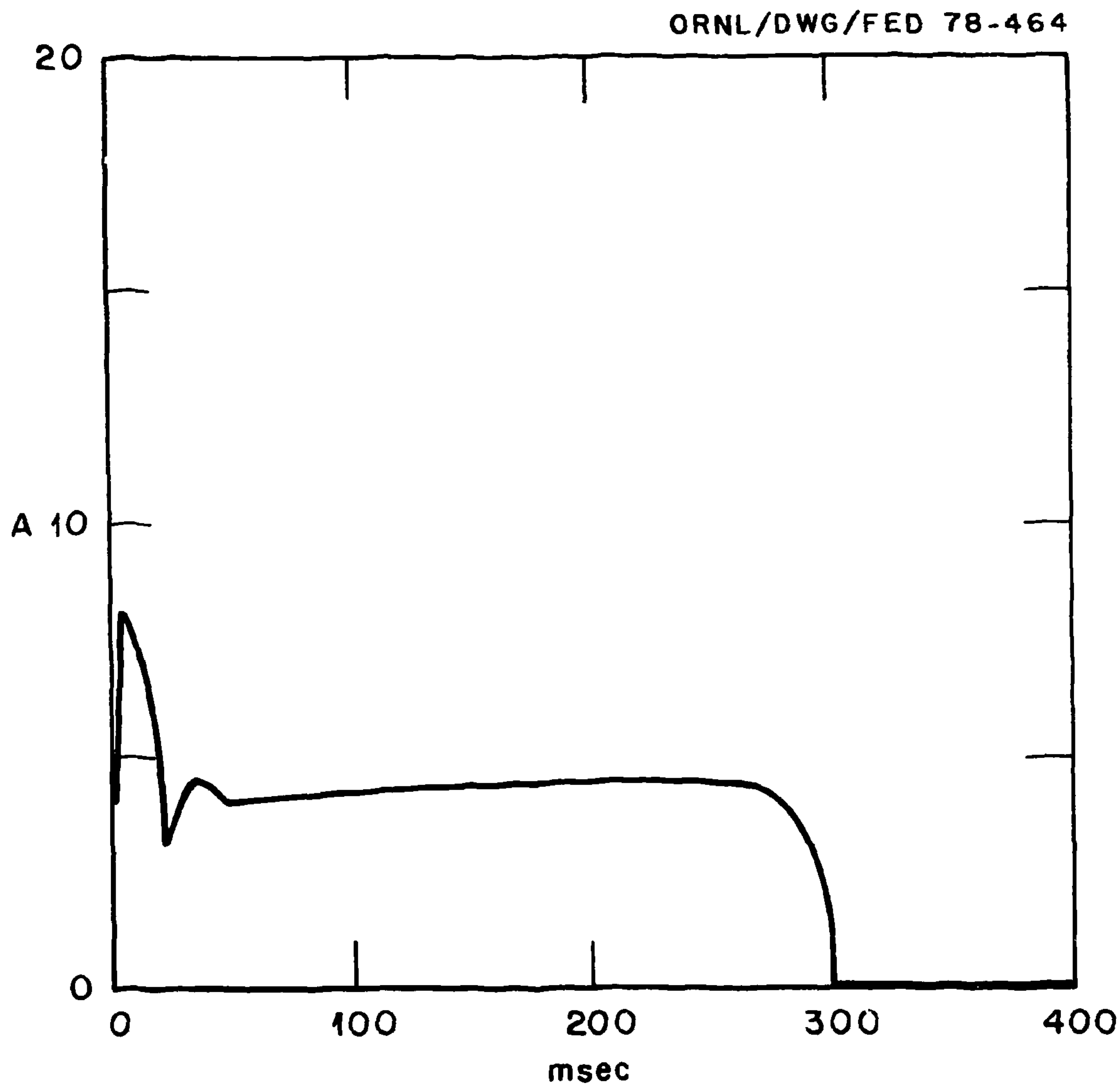

Fig. 3. Decel current waveform as displayed by VT-11 graphic terminal. Other waveforms which may be displayed are decel voltage, accel current, accel voltage, arc current, and beam current.

PROBLEMS ENCOUNTERED

While the data acquisition system works, there are some problems. Difficulty in making rapid changes in the MBD data acquisition routines is caused by the MBD's unusual instruction set and memory mapping scheme, coupled with the PDP-11 assembler macros used to assemble the MBD's programs. (The MBD was chosen for its speed and not for ease of programming.)

Another problem encountered was that the equipment turned out to be configuration sensitive. Originally, the MBD was on the processor side of the UNIBUS with respect to the VT-11 display. While either the VT-11 or the MBD would operate alone, they would not operate simultaneously for more than a few seconds. No logic malfunction could be found that would account for this situation. Careful analysis of UNIBUS signals indicated that the problem was caused by two things: the MBD's and VT-11's high speed demands on the direct memory grant control process and ringing of the UNIBUS control lines due to the high speed digital signals and loading of the UNIBUS. The problem was resolved by putting the MBD at the far end of the UNIBUS.

Some of the data acquisition problems associated with the CAMAC equipment were caused by misreading of the technical specifications or by a misprint in the information provided. It is worthwhile to test all functions on a new type of CAMAC module to verify that the module meets CAMAC specifications as well as the manufacturer's specifications. The CAMAC equipment's standardization and modularity simplified the problem of interfacing with the beam test stand.

Noise generated when the beam fires interferes with the computer system. The noise problem is worst when the source breaks down. The line printer is affected most often; also, the VT-11 loses information, and random crashes of the PDP-11 processor occur.

Steps taken so far to reduce this noise include the use of software error recovery routines for the line printer and installation of a grounded copper plate in the PDP-11 processor. These measures reduced the effects of noise, but there were still occasional computer crashes when the beam was firing. More electromagnetic shielding was installed around the source, and this seems to have solved the problem.

CONCLUSIONS

The data acquisition system has been useful for obtaining information concerning power distribution profiles and beam focusing. This is especially true of the VT-11 tabulated power distribution display, which appears less than 2 sec after the data are acquired.

Plans for the future include permanent data storage on magnetic tape, hard copy graphics output to the Versatec printer/plotter, enhancement of the VT-11 data display, and automation of source operation.

REFERENCES

1. Trademark of Digital Equipment Corporation, Maynard, Massachusetts.
2. BI-RA Systems, Inc., 3520-d Pan American Northeast, Albuquerque, New Mexico.
3. Institute of Electrical and Electronic Engineers, Inc., Standard No. 583-1975.