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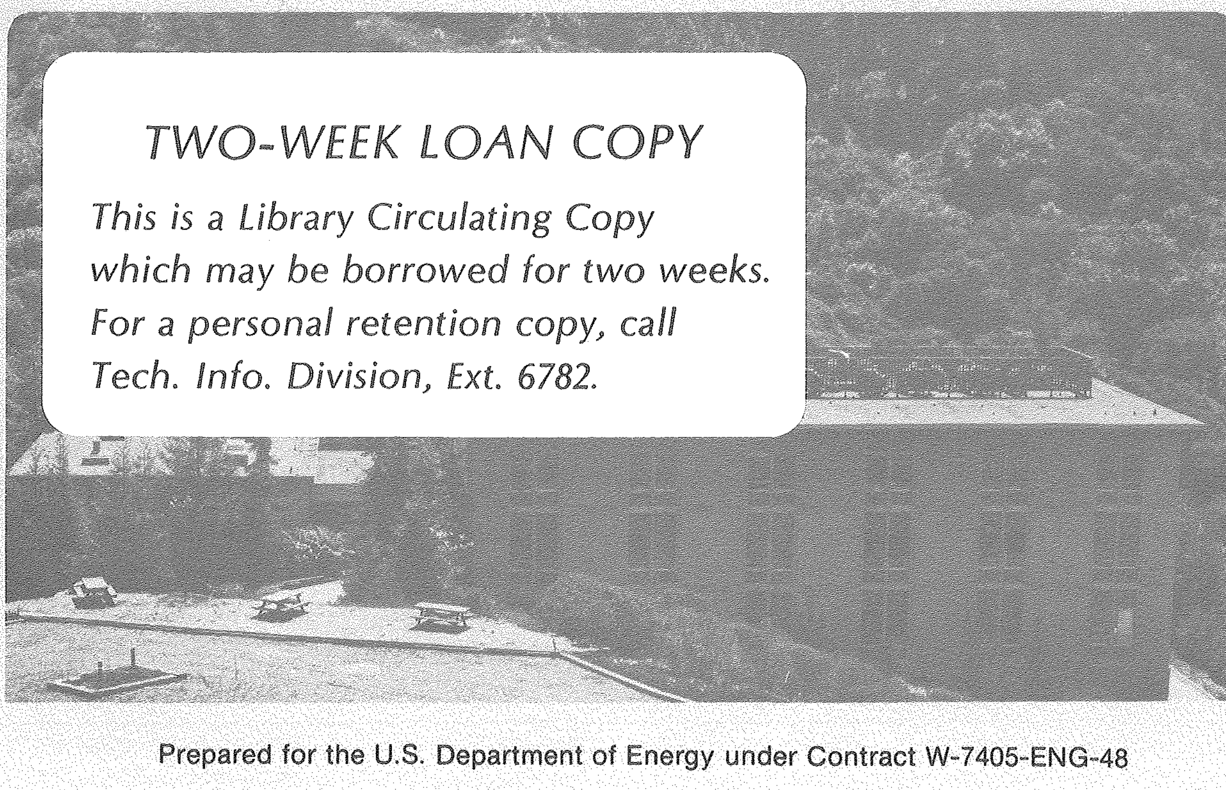

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LSI-11 MICROCOMPUTER-BASED DATA ACQUISITION SYSTEM FOR AN OPTICAL MULTICHANNEL ANALYZER

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Abstract

A microcomputer based operating system for programming and data acquisition from a two dimensional target optical multichannel analyzer used for high-speed UV/visible spectroscopy is described. The hardware and software interfacing requirements for such a system to provide dedicated real time data acquisition is considered. It is found that a relatively simple parallel interface to an inexpensive microcomputer can be properly configured to perform adequately for high-speed image processing.

INTRODUCTION

The emergence of the optical multichannel analyzer (OMA) [1] as an instrument for two dimensional electronic imaging has allowed for extremely high-speed signal processing capabilities as well as to provide a means of detection of optical signals in instances where no other practical means is possible.[2,3,4] Based primarily on the existing television vidicon technology, the programmable optical multichannel analyzer has been enhanced to provide both extremely broad spectral sensitivity (200-800 nm) as well as excellent quantum efficiency (Q.E.=2-10%). The ability of the optical multichannel analyzer to record spectral information has given atomic and molecular spectroscopists an advantage in speed and accuracy of data collection, especially when one considers the recent advances made in the peripheral area of high-speed digital signal processing capabilities.

In this paper we would like to describe the use of a dedicated LSI-11 to provide real time data acquisition from the OMA 2 optical multichannel analyzer. The software is packaged to be sufficiently simple, yet comprehensive, and is applicable to anyone with access to any one of the many PDP-11 family computers, in particular for LSI-11 microprocessors operating under the Digital Equipment Corporation (DEC) RT-11 disk operating system.

While the interfacing of digital instrumentation to computers for control and data acquisition is generally straightforward, this particular interface of the OMA to an LSI-11 requires some rather special considerations. Because of rather rigid constraints related to high-speed image processing, the timing requirements for the I/O can be rather intricate. Through the efficient coupling of both hardware and software, the LSI-11 can be made to perform successive buffer additions within the time limits, without the need to build special hardware adders.

Since it is written in standard FORTRAN IV and in MACRO-11 assembly language, it can also be made to run in any other PDP-11 operating system (RSX-11, RSTS, etc.) with no modifications with the possible exception of necessary software address changes to reflect particular system configuration device handlers and specific file management CALL subroutines.

The optical multichannel analyzer system consists of three parts: 1.) the Princeton Applied Research Corporation (PARC) 1254 SIT detector 2.) the PARC 1216 Detector Controller and 3.) DEC LSI-11 computer. This data acquisition system replaces the PARC 1215 OMA 2 Console, which uses a software package written in the FORTH language.[5,6] The software for this operating system is totally written in the high-level language FORTRAN IV, except for several FORTRAN-callable, assembly-level I/O routines.

There are several advantages for development of this OMA 2 Data Acquisition System[7,8] in our laboratory. The most important consideration is compatibility with an existing (and much more powerful and expandable) DEC RT-11 based system with its advanced software capabilities. Our RT-11 disk operating system, not only supports an LSI-11 based network system (REMOTE-11), but numerous peripherals including graphics with hardcopy.

Furthermore, since this operating system is built on any PDP-11 general purpose computer, one has the ability to efficiently use the computer for many other laboratory functions, as well as for programming needs of data reduction and analyses. Furthermore, custom modifications by users for specific applications are far simpler, since FORTRAN is a much more universally accepted programming language than is FORTH.

I. DATA ACQUISITION SYSTEM CAPABILITIES

Use of the optical multichannel analyzer in conjunction with a dispersive monochromator allows one, in effect, to digitally process an entire lineshape function simultaneously. This not only relieves one of the necessity to scan the frequency region of interest, but also makes lineshape studies easily accessible for transient optical signals.

The user of the optical multichannel analyzer interactively runs a series of routines from a Tektronix graphics terminal connected to an LSI-11 microcomputer. The LSI-11 computer is configured to operate under DEC's RT-11 V3B operating system which also supports a hardcopy terminal, a hardcopy graphics plotter, as well as two digital-to-analog converters (DAC).

In the first part of the program, the user selects the scan parameters for a particular scanning routine, which are then translated into instructions for the 1216 Multichannel Detector Controller. These scan parameters include the region(s) of the target to be scanned, the dwell time in any particular channel, and the total number of scans to be accumulated in memory.

A 14-bit analog-to-digital converter presents the data synchronously to a 16-bit TTL bus which is then added into memory by the computer. A single-ended handshake was built into the interface to improve system integrity.

The user also collects a background scan, in order to subtract out any effects of concomitant dark current. At this point, the data may be viewed directly, plotted on the graphics screen or hardcopy terminal, or stored in a data file on a floppy diskette. One can also look at a previously collected data file, repeat the experiment, or perform a different scanning routine.

Low light level signals may be detected by using extended delay target integration methods. Since dark current may be a substantial fraction of the signal detected by the OMA under certain conditions, one can reduce the dark current by as much as 10^4, by cooling of the detector to -60° C by means of a liquid ethanol bath. Light is allowed to integrate on the target for a pre-determined amount of time and is then read off with a much higher signal-to-noise ratio. Operations in extended delay require the LSI-11 computer to interactively program the 1216 Multichannel Detector Controller so as to prepare the target for optimal reading efficiency.

We have developed this operating system so as to offer the user the ability to easily implement other scanning features as special applications might require. Such features which we have implemented include multiple tracks data collection and time resolved electronic shuttering of the OMA detector[9,10,11], which then allow us to electronically record more than one aspect of a transient optical experiment simultaneously.

During the data valid time interval, the software logic must:

1.) Check for DATA VALID

2.) Check for LAST CHANNEL flag

3.) Double precision add 14 bits of data to buffer

4.) Clear DATA VALID flag,

as well as periodically input new scan parameters during data acquisition operations, such as in extended delay target integration and electronic detector gating. Reliability is tested for at the end of each scan routine. One should note here that the 1216 presents the data synchronously and that the handshake is really only a single-ended one. Furthermore, interrupts are not generated, nor is DMA required; instead, the processor polls the device status address for a DATA REQUEST signal.

II. OPTICAL MULTICHANNEL ANALYZER DATA ACQUISITION SYSTEM IMPLEMENTATION

A. INTERFACE CONSIDERATIONS

The interface for the PARC Model 1216 Multichannel Detector Controller is provided through a 16-bit DEC DRV11 parallel interface board by means of processor control. This interface provides both scan instructions to the 1216, as well as real time data acquisition from the detector controller. The digitized data from the OMA Controller is collected and summed in real time through a 16-bit parallel interface at up to 25 K words/second.

Since the data must then be stored in real time, the computer must acquire the data during the data valid period of the channel dwell time. The user may choose dwell times/channel of between 20-140 μsec. The timing sequence is shown in Figure 1. The worst case data valid period is 9 μsec for dwell times of 20 μsec. Unfortunately, the LSI-11/2 CPU cannot handle the necessary instruction executions within these time constraints. Thus for operation of the OMA 2 in this system, 40 microseconds/channel is the minimum dwell time allowable. In almost all applications, this represents a very minor limitation.

B. HARDWARE

The hardware for the data acquisition system is seen in Figure 2. The optical multichannel analyzer (OMA 2) is interfaced to the LSI-11 microcomputer through a 16-bit parallel I/O card. Any suitable video monitor or CRT display is used to provide a real 2-D display of the target. The PARC 1216 Multichannel Detector Controller stores the op codes for the scanning routines and also provides a 14-bit dynamic range A/D converter which presents the digitized signal intensity in real time synchronously to the LSI-11 computer.

The detector used on our laboratory is the Model 1254 silicon intensified target (SIT) tube with a UV scintillator coating to extend its S-20 response into the UV. The target is a 500x500 channel silicon diode array with approximate dimensions of 1.5x1.5 cm. To reduce dark current, the detector can be optionally enclosed in a dry ice cooled housing, which we have modified into a closed system liquid ethanol refrigeration unit. Peripherals for the data acquisition system include a Tektronix console graphics terminal and hardcopy plotter[12], an ADAC Corporation 12-bit multiplexed A/D and DAC, a DECwriter, and the system device is a dual floppy disk unit from Data Systems Design.[13] An oscilloscope is used to obtain a real time spectrum display.

A typical LSI-11 backplane configured in our laboratory contains the following microcomputer module components. An LSI-11/2 CPU card and 32 K memory card (Monolithic Systems) occupy the first two slots in the Q-bus. A DEC DRV11, used to provide parallel I/O to the 1216 Multichannel Detector Controller, is given a high priority daisy chain bus position. The backplane includes a floppy disk interface card as well as DEC DLV11 serial I/O cards to the Tektronix console terminal as well as a DECwriter hardcopy terminal. An ADAC 600 LSI11 card containing 16 multiplexed A/D channels with two programmable gain digital-to-analog converters is included to provide system monitoring and other laboratory digital voltage measurements.

C. SOFTWARE

The software is comprehensive and requires 24 K memory. It may be shortened depending on whether the user requires all of the features of the system. Also, one can expand it easily with the use of overlays.

It is written in FORTRAN IV except for some input/output routines written in the MACRO-11 assembly language. Users can change the FORTRAN software with little trouble as their specific applications might require, since the software is written in a rather modular fashion.

Figure 3 shows the interface registers and their functionality on the DRV11 parallel input/output board. Bits 15 an Ø7 are used to test for the DATA VALID and LAST CHANNEL flags, respectively. INTERRUPT ENABLES A and B are set at Ø to inhibit vector interrupt generation. CSR1 is used for the EXTERNAL EVENT FLAG which can be used for applications requiring EXPERIMENT START triggers, or for tagging data events.

DROUTBUFF is a read/write buffer area for input to the 1216 controller. These bits effectively override the front panel toggle switches on the 1216. DRINBUFF is a read only buffer containing the synchronous data from each channel as the OMA scans. All of the controls for the input buffer DRINBUFF and status register DRCSR are written in MACRO-11 for speed and simplicity.

In the OMA 2 Data Acquisition System, the user interacts at the terminal console. A flow chart for the data acquisition software is seen in Figure 4.

The program is loaded from a floppy diskette upon which time several questions are asked about the user's system configuration. After the initialization process is completed, the user has the opportunity to avoid the data acquisition portion of the software and may proceed directly to the LOOK subroutine in order to view and perform data massage of a previously collected data file.

In normal operation, a directory is presented to the user, allowing him to change scan regions of the target, dwell times, and number of scans to signal average, as well as many other options. When the user has determined a set of mutually compatible scan instructions, he is allowed to proceed to data collection. A background collection of the associated dark current is collected and stored in a background buffer area. Signal collection proceeds after which time the user is given the opportunity to subtract out the background and replace his signal data buffer with the signal-only normalized data.

At this point, the user can perform any of the following routines. He may REPEAT the scan routine with or without first zeroing the data buffer, he may SAVE the data and its scan parameters, as well as his own comments about the experiment on a floppy diskette, or he can LOOK at previously collected data stored in a data file.

The user has the ability to LIST or PLOT the data. Plotting includes the ability to smooth the data and display the spectra on the graphics terminal as histograms, line spectra, or point spectra. Figure 5 shows a typical plot generated by the graphics plotter. The software used for graphics is an assembly level condensed version of the Tektronix PLOT-10 software package. Finally, the user has the option to QUIT the program and return back to the RT-11 monitor.

III. ALTERNATIVE APPLICATIONS OF OPTICAL MULTICHANNEL ANALYZERS

It is becoming increasingly clear that electronic imaging technology will play an important role in many scientific as well as commercial industries.[14] For example, in the medical instrumentation area, the development of the X-ray CAT scanner for high-speed medical diagnosis has proven to be an invaluable tool. Secondly, the development of economic, yet powerful, microprocessors to perform data acquisitions, pattern recognition, and data storage is equally impressive. Thus, it is in the area which combines both the state-of-the-art electronic imaging as well as high-speed computer data manipulation will the greatest potential be realized.

In industry, the implementation of optical multichannel analyzers, reticon arrays, and CCD array packages, has begun to see use for the control monitoring of many clinical and manufacturing processes. Finally, we hope that this report provides sufficient evidence that rather low-cost, dedicated microcomputers can be made to perform quite favorably in many imaging applications.

IV. DISCLAIMER

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

Acknowledgements: Special thanks go to Dr. Jonathan L. Weber and Paul W. Roehrenbeck of Princeton Applied Research Corporation for many helpful suggestions for programming the CMA. This work was supported in part by National Science Foundation and by the Division of Chemical Sciences, Office of Basic Energy Sciences, U.S. Department of Energy under Contract No. W-7405-Eng-48.

References and Footnotes

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Figure Captions

Figure 1: Timing sequence for interface of 1216 Detector Controller to LSI-11 through a processor controlled 16-bit parallel port.

Figure 2: Components of optical multichannel analyzer (OMA 2) data acquisition system for spectroscopic applications in a laboratory environment.

Figure 3: Interface Registers in PDP-11 for parallel port I/O to 1216 Multichannel Detector Controller.

Figure 4: Flow chart for OMA 2 Data Acquisition System software.

Figure 5: Typical optical spectrum collected using Extended Delay Target Integration. This is a high resolution (.1 cm^{-1}/channel) collected from Fe hollow cathode lamp at 3752 Å.

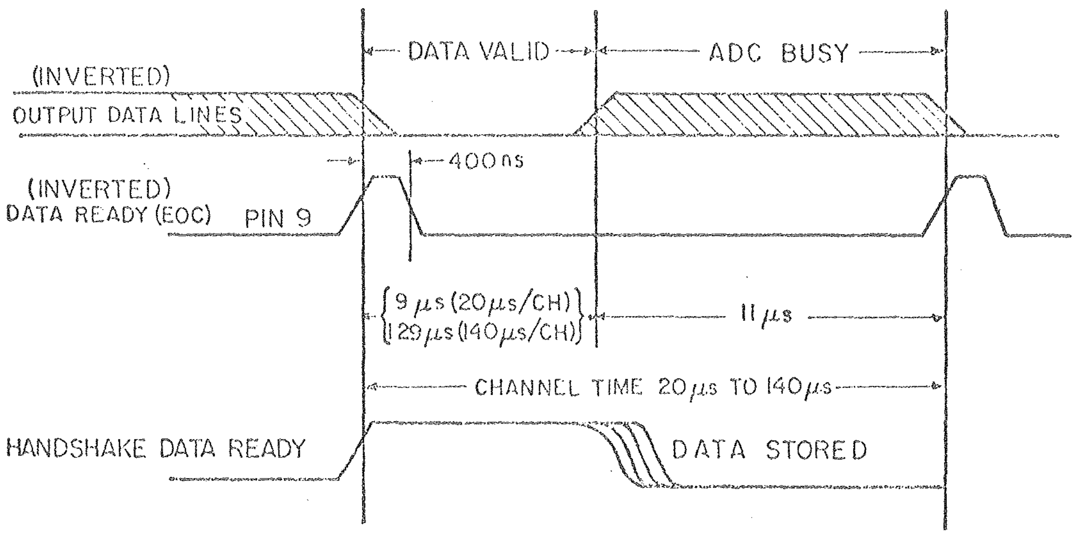

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Figure 1

LSI-II BASED OPTICAL MULTICHANNEL ANALYZER DATA ACQUISITION SYSTEM

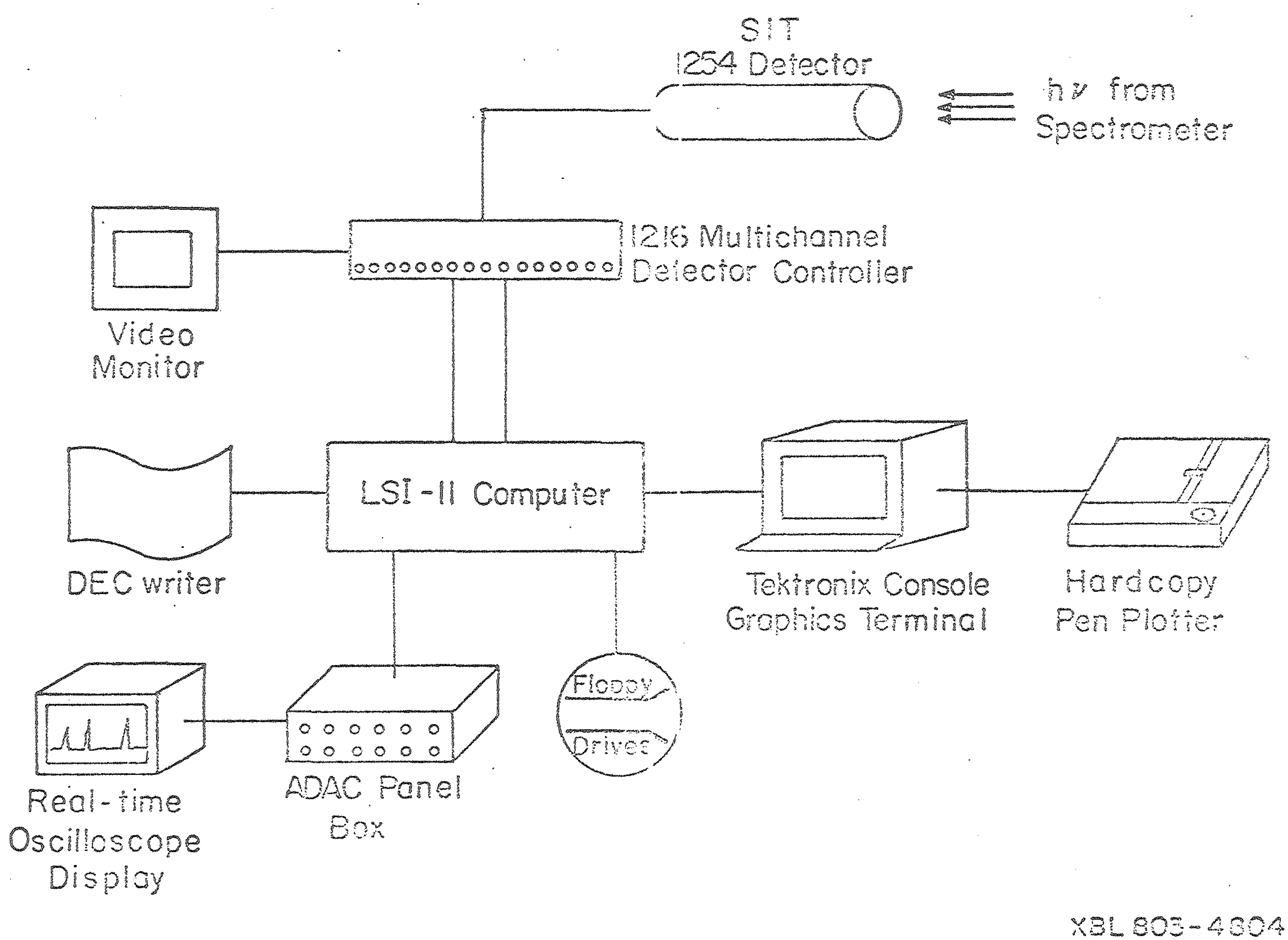
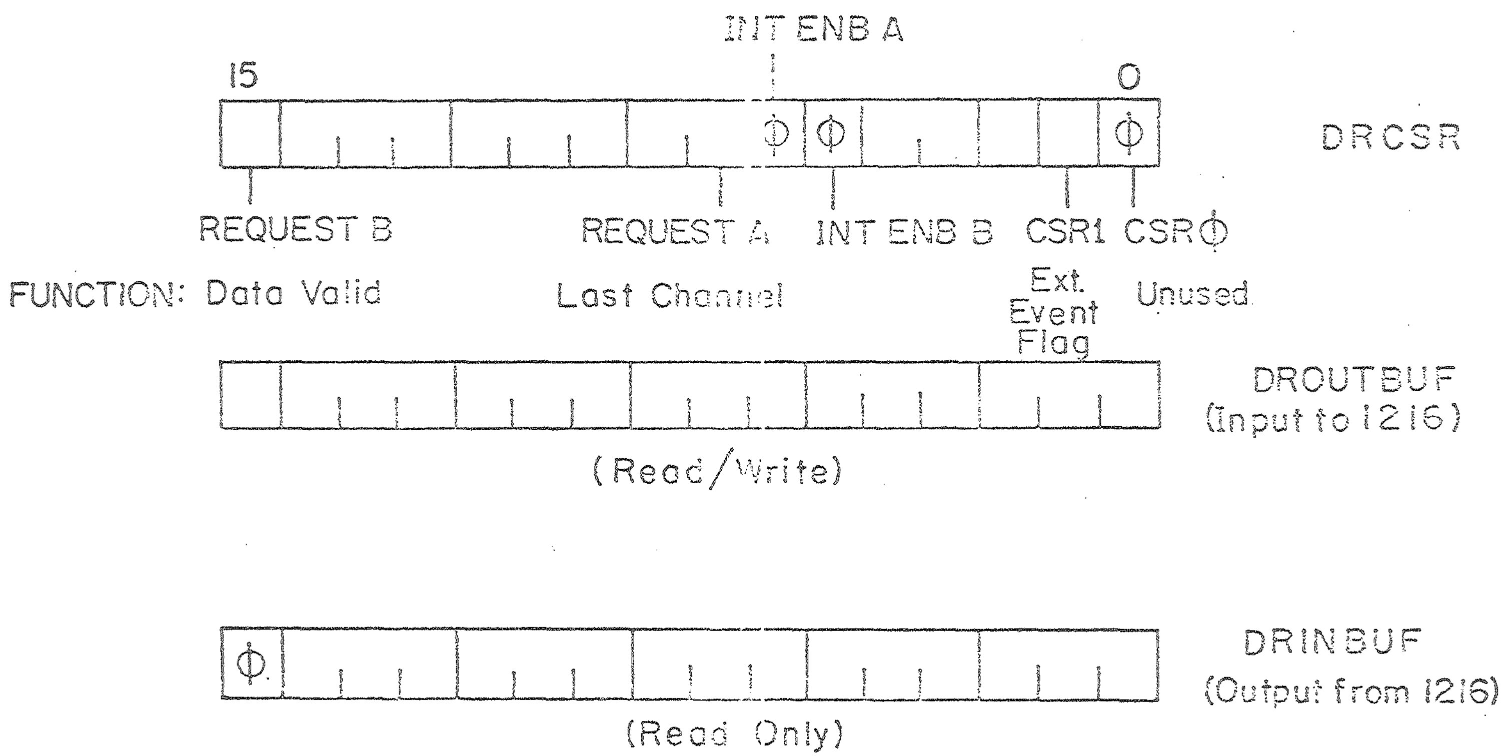


Figure 2

INTERFACE REGISTERS FOR DRV11 PARALLEL PORT I/O TO OMA 2 1216 MULTICHANNEL DETECTOR CONTROLLER



	Address	
DRCSR	167760	Status Register
DROUTBUF	167762	Data Out Buffer
DRINBUF	167764	Data In Buffer

Vector Address-314 (unused)

XBL 803-4805

Figure 3

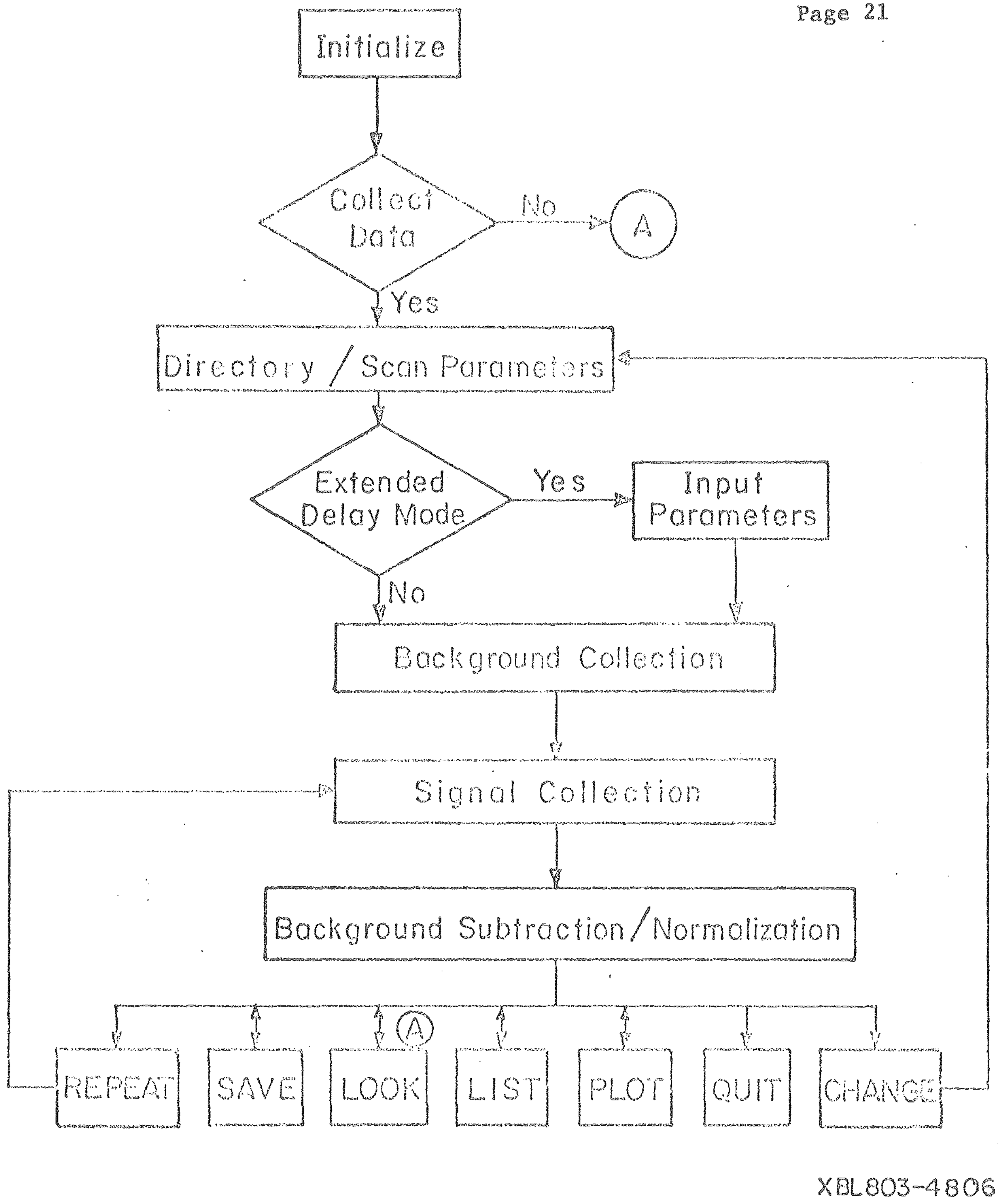

Initialize
Collect Data
No
A
Yes
Directory / Scan Parameters
Extended Delay Mode
Yes
Input Parameters
No
Background Collection
Signal Collection
Background Subtraction/Normalization
A
REPEAT
SAVE
LOOK
LIST
PLOT
QUIT
CHANGE
XBL803-4806

Figure 4

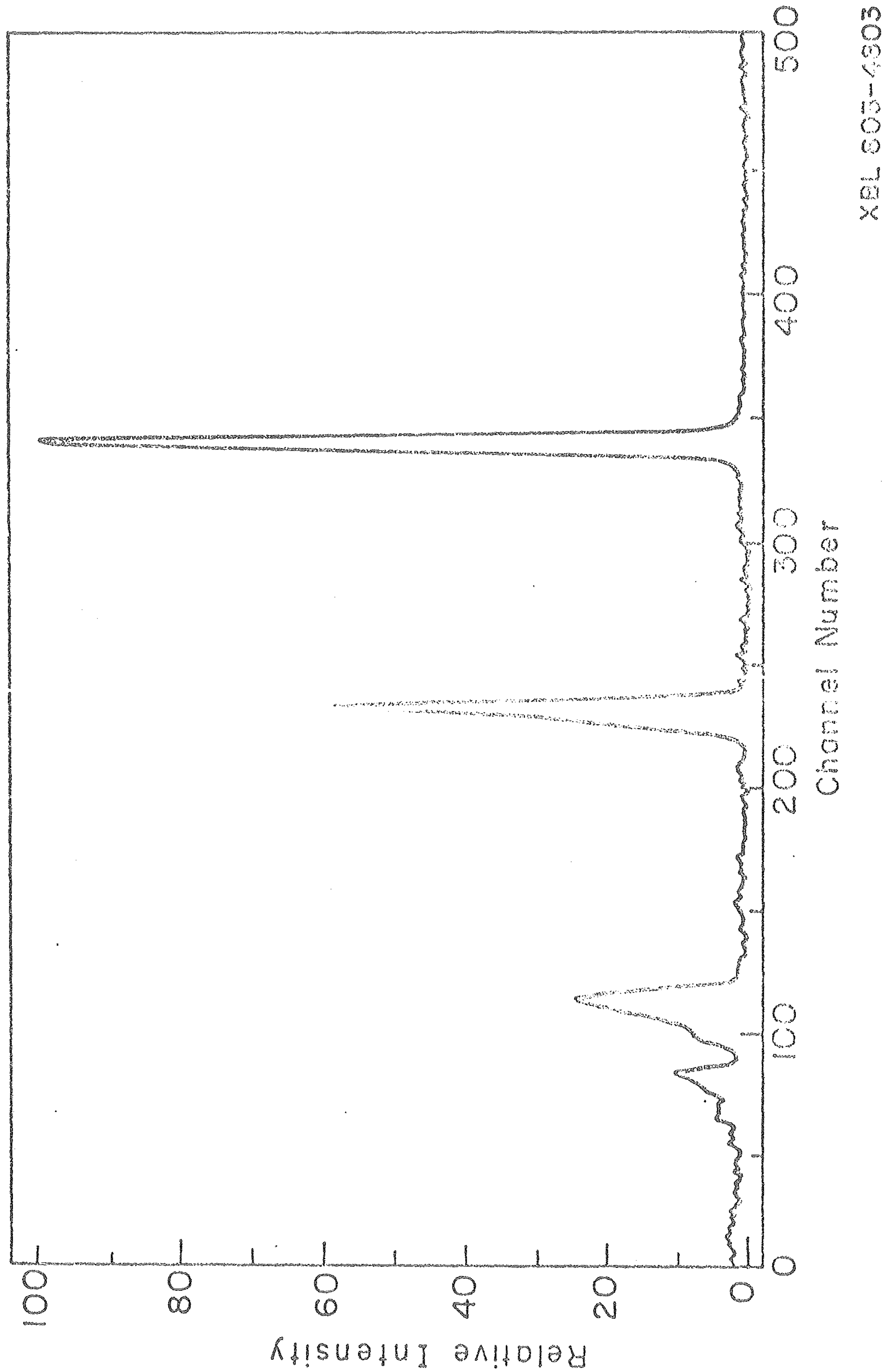

Relative Intensity
0
20
40
60
80
100
Channel Number
0
100
200
300
400
500
XBL 803-4903

Figure 5