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AN ACOUSTIC DATA ACQUISITION SYSTEM FOR RESEARCH ON PELAGIC FISH SCHOOLS

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TABLE OF CONTENTS

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ABSTRACT

This document describes a small, flexible acoustic data acquisition system which was developed for studying the acoustic signatures of pelagic fish schools. The hardware was centered about a PDP-8/L mini-computer. Hardware interfaces to peripheral data gathering and display devices are described in detail. A unique software system was developed for use with the data acquisition system at sea. The software is an interpretive, algebraic-like language with special high level functions and commands designed to service the system hardware. A detailed description of the major elements of this flexible software system and its operation are provided.

I. INTRODUCTION

A recently completed research program[1/] dealt with the use of underwater acoustics as a tool to assist in the remote identification of schools and aggregations of marine fish. During the execution of this research, a data acquisition system was developed for use at sea in conjunction with two existing sonar systems. The purpose of this document is to provide a relatively short, but detailed description of the hardware and software developed for use as a tool in conducting the fisheries research. A brief description of the research program follows.

Explosive acoustic sources were used to obtain echoes from aggregations and schools of commercially important marine fish. Narrowband spectral analysis of the echoes from these targets revealed significant structure in the frequency range from 200 Hz to 5 kHz. The targets were partially captured after the acoustic tests; three yielded northern anchovy (Engraulis mordax), one consisted of a mix of anchovy and jack mackerel (Trachurus symmetricus) and the last sample contained an aggregation of seven species of rockfish (Sebastes), a whitefish (Caulolatilus princeps) and a striped seaperch (Embiotoca lateralis).

The results of the direct biological sampling were combined with theoretical predictions for the resonant swimbladder response and compared with the experimentally observed resonances.

The results of the study indicated that it is feasible to demonstrate the presence of swimbladder-bearing fish in a school by acoustic methods. Determination of the average swimbladder size was also shown to be practical.

Accurate acoustic observations of the movements of three pelagic fish schools were made and are discussed in Reference 1. The motions observed were divided into two classes.

The track and the swimming speed of the school was interpreted in terms of cruising speed and the magnitude and duration of high speed swimming bursts, to give estimates of the average fish length in each school.

Internal school dynamics was investigated with the one-half second acoustic pulses from a 30 kHz sonar. Echoes resulting from these transmissions were analyzed to determine the frequency distribution of echo energy. The observed frequency distributions were interpreted as resulting from doppler shifts due to motion in the fish school. Observed doppler structure was divided into that caused by body and tail related swimming motions, near side aspects, and to behavioral swimming characteristics, near tail or head aspect.

Side aspect data were used to estimate fish length. The estimates so derived were consistent with the estimates of fish length made on the basis of school swimming speeds.

Tail and head aspect doppler structure data were correlated with echo level, school dimensions and school swimming speed to demonstrate that the observed doppler structure could have resulted from unique swimming behavior. In two cases, the behavior changed the school dimensions and in a third situation no change in school dimensions were observed.

II. HARDWARE

A. Data Acquisition System

In the course of planning the research summarized in the introduction, it was apparent that the swimbladder resonance work could be carried out with a substantial savings in time and effort if a computer were employed in the data and signal processing phase of the work. In addition, it was determined that a computer controlled data acquisition system was a highly desirable, if not essential, tool for use in acquiring the data on doppler structure in fish school echoes. The degree of flexibility, in both hardware and in software, provided by such a system was of proven value at the end of the project.

The principal elements of the final data acquisition system were a Digital Equipment Corporation PDP-8/L® mini-computer and a Federal Scientific UBIQUITOUS® UA-10 Spectrum Analyzer with a Model UA 1010 Spectrum Averager. Peripherals included an ASR-33 Teletype with a low speed paper tape reader and punch, a Remex Model 3075 high speed paper tape reader/punch, four single data track digital cassette tape recorders, an X-Y plotter, three 8 bit D/A converters, and a computer controlled 8 channel analog multiplexer. Also included were a single 10 kHz 12 bit A/D converter, a computer driven CRT display, three independent facilities for supplying pulses of both positive

and negative polarity at two voltage levels and two pulse widths to external devices, a hard copy display unit and a facility for interrupting the computer from an external source.

Interfaces for all devices except the teletype and the high speed reader/punch were designed and fabricated during the course of the research. It is not within the scope of this report to describe each device and its associated interface in the detail available in the logic diagrams and wire-wrap lists.* Rather, a general description of the function of each device will be attempted. The sequence following the execution of each machine language external device operation code will also be described. A narrative description of these two subjects does not exist elsewhere and is presented here for the reference of future system users. No attempt will be made to describe the method of interfacing the external devices to the PDP-8/L computer as the standard procedures described in DEC literature[2/] were generally followed closely.

The Computer

The PDP-8/L computer configuration used as the principal component of the data acquisition system is a programmable data processor with 8192 12-bit memory words. Its memory cycle time is 1.6 microseconds. The machine instruction set includes microprogramming capabilities and both auto-indexing and program interrupt facilities are available.

Additions are performed in 2 machine cycle times or 3.2 microseconds when one 12-bit number is already in the accumulator. Subtractions take 6.4 microseconds when the subtrahend is in the accumulator. Multiplication of two signed 12-bit words is performed by a software routine and results in a 24-bit

* Complete logic diagrams and wire-wrap listings are available at the physical location of the data acquisition system. This material is both sufficiently specific to the system fabricated during this research and sufficiently bulky that its interest to the general reader does not warrant its inclusion in this memo.

product in approximately 336 microseconds. Division of two signed 12-bit numbers produces a 12-bit quotient in the accumulator and a 12-bit remainder in core in about 474 microseconds. The division is also a software function. All numerical manipulations are performed in two's complement arithmetic.

Two modes of interfacing are available, programmed I/O and direct memory access (data break). In programmed I/O, control of each data transfer or external operation is under the control of the program being executed. This mode of interfacing was used for all but one of the peripherals in the data acquisition system. The hard copy display unit (a modified Ross depth sounder recorder) uses the direct memory access channel.

The direct memory access channel provides a means of bidirectional core access which is independent of the program currently being executed by the computer. The transfer of data to and from core does not use either the accumulator or the auto-index registers. Two sequential core locations in memory field zero are used to control the location of reading or writing in core and the number of words to be read or written. The location of the first of these two words is selectable by switch register on the front panel of the data acquisition system.

A high speed digital multiplexer is provided in the data break interface for future expansion. The multiplexer is currently hard wired to channel 0.

The Teletype/Reader/Punch

The ASR 33 teletype is used as the principal input/output device in the data acquisition system. Input may be either through the keyboard or through a low speed (10 characters per second) paper tape reader. Output is either typed or typed and punched at 10 characters per second. The interface for this device is located in the computer main frame and is a serial-to-parallel converter for teletype inputs to the computer and converts from parallel-to-serial

format on computer output. All input and output is formatted in an 8-bit ASCII code. The teletype uses device codes 03 and 04. A complete description is available in the Small Computer Handbook.[3/]

The High Speed Reader/Punch

The high speed reader/punch used in the data acquisition system was a REMEX Model 3075. The interface for this device was purchased from the manufacturer and is located in the PDP-8/L main frame. The interface is standard TTL logic, packaged on two double sized boards.

The optical reader operates at a maximum speed of 300 eight-bit characters per second and has a stop-on-character capability. The punch operates at a maximum speed of 75 eight-bit characters per second. The reader/punch uses device codes 01 and 02. The interface is compatible with the standard DEC hardware and software and is described in detail elsewhere.[4/]

Hard Copy Display Unit

A Ross Laboratories Fine-Line Model 400-A recorder originally built for an echo sounding application was modified for use in the data acquisition system.

The recorder stylus runs at a constant rate and travels from right-to-left on the recorder paper. Four pulses are generated during each complete revolution of the band which carries the stylus across the paper. Any combination of these pulses can be selected for application to a single line which goes to the computer interface by setting one or more of four range selector switches on the recorder front panel. In normal applications the switch settings used should produce a single pulse at the time the stylus begins its traverse across the paper. This pulse is transformer-coupled to a pulse shaping network and then used to start a transfer of data from the computer core to a 3-bit D/A converter via the data break channel. The data transfer is in 12-bit words and

is unpacked in the interface into four 3-bit bytes. The transfer rate is controlled by a simple oscillator built with a TTL NAND gate, two resistors and a capacitor. One of the resistors is variable over a sufficient range to allow an adjustment of output rate. This controls the length of mark for each data point and thus the total extent of the data across the paper for a fixed number of data points.

The D/A converter was specially designed and fabricated to allow independent adjustment of the voltage at each of the eight levels. This was done in order to allow compensation for the non-linear marking density of the special paper used in the recorder.

The number of words transferred from the computer core to the interface is controlled by a memory register in memory field zero. The location of this register, called the word count register, is selectable by setting a binary switch on the front panel of the interface cabinet. The word count register must contain one less than the two's complement of the number of 12-bit words to be transferred before the transfer and must be reset to the proper number before each line of data is written to the recorder. The contents of the word address counter are incremented during the transfer of each word during the data break operation.

The word in core memory immediately following the location of the word count address is designated the current address register. This register initially contains the 12-bit address, in either memory field zero or memory field one, of the first word to be transferred. The contents of this register are automatically incremented during the block transfer and must be reset before each new transfer.

The memory field from which data is taken to be displayed is controlled by the command issued. The Ross recorder hard copy display uses device code 15. Execution of the instruction 6151 causes the computer to skip the next

instruction if the Ross recorder is running and is ready to accept a new command. Execution of the computer instruction 6152 causes a single line of data to be written on the recorder from a sequence of addresses starting with the memory field zero address specified by the current address register. The instruction 6154 performs the same function in memory field 1. The write instructions are singly buffered, that is a new write instruction may be issued before the previous line has been completed. This buffering is only effective, however, if the conditions tested by the skip command 6151 are met. The use of the microprogrammed instructions 6153 and 6155 are therefore recommended to insure that conditions for a successful write operation have been met. Since the stylus moves from right-to-left, the data must be loaded into memory in reverse order for normal left-to-right display.

Spectrum Analyzer

The Federal Scientific UBIQUITOUS® spectrum analyzer is a hybrid device, employing both digital and analog technology. The instrument employed in the data acquisition system was Model UA-10. This model computes 200 point Fourier transform in real-time for selectable frequency bands varying from 20 Hz to 20,000 Hz. The system frequency resolution varies with the analysis bandwidth selected. The instrument employs a time-compressed, recirculating, 8-bit digital shift register memory for storage and an analog stepping-scan filter processor for the frequency analysis. The current contents of memory, the magnitude, magnitude squared and logarithm of the Fourier transform of the input signal are each available as analog signals from the analyzer. A transient hold mode allows capture and recurrent analysis of transient signals. This mode must be initiated and cancelled by externally applied signals.

The computer interface to the spectrum analyzer is built from series 7400 TTL logic and is located in the main interface cabinet. A computer command summary follows.

Most devices interfaced to the PDP-8/L computer must have a status flag. This flag is used to indicate that the device is ready to accept and execute a new command or requires servicing by the computer. The method of checking the device status is the execution of a computer command which checks the device flag. If the flag is set (logic 1) the device is considered ready, the computer skips the next instruction (usually a jump command), sets the flag to logic 0 and proceeds to service the device. This command is frequently microprogrammed with device service commands to save program storage space and to speed program execution. The "skip on ready" command for the spectrum analyzer is 6102. The flag is set by the initialize pulse when the start switch is depressed on the computer. The flag can also be set by the computer instruction 6104. The instruction 6101 is used to clear the flag under program control.

The spectrum analyzer has a provision for either internal or external stepping through the analysis frequency range. In the internal address mode, the analyzer will run automatically. The frequency analysis rate will be controlled by a clock in the analyzer. To enable the internal address, the command 6632 must be executed. To clear the spectrum analyzer status flag before enabling the internal address, one may use the microprogrammed code 6633. If it is desired, one can clear the status flag, enable the internal address and set the status flag after a 4 microsecond delay by executing the instruction 6637. This facility is useful but must be handled with extreme care. Any input/output pulse number 4 (IOP4) resulting from execution of input/output transfer (IOT) commands using device codes 10, 63, 67, 70, 71, 72, 76 or 77 will cause an input/output skip (IOS) if the spectrum analyzer status flag is set during the interval from 4 to 4.5 microseconds after the IOP4 pulse. In general, IOT's

for this interface and for the A/D converter interface cannot follow any IOT which generates IOP4 by less than two 1.6 microsecond memory cycle times without causing a potentially erroneous skip of a program instruction.

To enable the external address, the command 6672 must be executed. In normal operations, a command (6702) is executed first to reset the analysis frequency to 0 Hz. The A/D converter is enabled and the voltage representing the spectral level at DC is digitized by the command 6772. The number can be read into the computer accumulator by the command 6774 as soon as the status flag has been set to logic 1. The flag is tested by the skip-on-ready command, 6102, which was previously discussed. Normally, the analysis frequency is then stepped by the instruction 6712 and the sampling sequence indicated above is repeated until all 200 analysis frequencies have been sampled. All of the commands discussed in this paragraph except the skip-on-ready command can be microprogrammed to clear the device status flag before execution by adding the number one to each command. To set the flag after a 4-microsecond delay add the number 4, except for commands 6772 and 6774. To clear the flag, execute the command and set the flag after a delay of 4 microseconds, add the number 5 to any of these instructions except 6102, 6772 or 6774. The restrictions discussed in the preceding paragraph apply to all of these microprogramming combinations.

Two further instructions are needed to operate the spectrum analyzer under program control. The first, 6772, causes a transient hold pulse to stop memory updates and hold in a recirculating mode the current memory contents for the analysis of transients. The second instruction, 6762, releases the transient capture mode and returns the memory to a continuous update mode. Both pulses are longer than 4.5 microseconds in duration. Both of these commands can be microprogrammed to clear the status flag before execution of the command (add 1) and/or to set the status flag after the command is

executed (add 4). The timing restrictions previously discussed must be respected in microprogramming these two instructions.

Analog-to-Digital Converter

The analog-to-digital (A/D) converter is a 12-bit CYCON Model 3235 converter. The maximum conversion rate is 10 kHz. The A/D converter interface is integrated with the spectrum analyzer interface and is located in the main interface cabinet. The converter has three input ranges, ±5 volts, ±10 volts and 0 to 10 volts. These ranges are selectable by a switch on the interface cabinet front panel. The A/D converter may be used with the spectrum analyzer or independently. An analog multiplexer, to be described later, allows up to eight inputs to be computer switched to a single output line. This line is normally connected by an external patch cable to the A/D converter input. The A/D converter input is buffered by a high slew rate, wideband, noninverting, unity gain operational amplifier.

The A/D converter utilizes the spectrum analyzer device status flag. This flag can be cleared by executing the instruction 6771. The instruction 6102 can be used to test the flag. The command 6772 will enable the A/D converter and digitize the voltage appearing at the converter input. The converter will set the device status flag when the conversion is complete. If the voltage at the converter input is overrange, the converter digital output is set to all zeroes and the overrange light on the interface cabinet front panel will be lit for 1 millisecond. To transfer the digital number to the computer, the instruction 6774 must be executed. This results in a jam transfer of the A/D converter output into the computer accumulator. Microprogrammed instructions 6773, clear flag and enable A/D, and 6775, clear flag before transferring digital number to the accumulator are legal. The codes 6776 and 6777 are illegal since no test for conversion completion is performed between A/D enable and the accumulator jam transfer.

Computer-controlled Analog Multiplexer

An eight line-to-one line MOS analog multiplexer is used in the data acquisition system. The address of the input line which appears at the output of the multiplexer is controlled by a 3-bit latch. The latch is loaded with the computer accumulator bits 9, 10 and 11 by the instruction 6511. Input capacitance is 3 pf at each channel. The channel own-resistance is less than 500 Ω. Multiplexer bandwidth is from DC to a frequency of 1 MHz. Crosstalk between channels has been measured and is better than -60 dB between 1 MHz and 1 KHz. Crosstalk is -70 dB or better at 100 Hz. The range of input voltages is from +15 volts to -5 volts. Exceeding these values may damage the device.

Spectrum Averager

A Federal Scientific spectrum averager, Model 1010, was interfaced to both the computer and to the spectrum analyzer. The spectrum averager normally operates under the control of the spectrum analyzer, accumulating a preset number of independent spectra, normalizing the resulting "ensemble" average and presenting the average for display in analog form. In the data acquisition system developed for use in the research reported in this document, an option to control the spectrum averager was implemented and located in the main interface cabinet. The interface is unique in the absence of a device status flag. Deletion of this flag was possible since all operations are performed in less than one computer memory cycle.

Six instructions are associated with the spectrum averager interface. They are: averager reset (6532), averager start trigger (6531), averager start (6534), averager erase (6571), set averager sweep gate (6572) and reset averager sweep gate (6574). Set averager sweep gate forces the averager sweep gate signal to a logic one and reset produces a logic zero on that line. The six instructions indicated above control the transfer of data from the

spectrum analyzer to the averager. These signals and their functions are described elsewhere in great detail.[5,6]

Magnetic Tape Cassettes

Four dual track magnetic tape cassette recorders also make up a part of the data acquisition system. One of the tracks is used for serial recording and playback of digital data while the other contains a prerecorded digital code used for synchronization of recording and playback of the data track. Data can be written to tape and is read from tape at the same rate, 300 eight-bit bytes per second. Data must be in block or file format since there is no stop-on-character capability. Packing density is 550 bits per inch. The units were designed and manufactured by International Computer Products (ICP). The hardware necessary for the parallel-to-serial conversion in write operations and the hardware for the serial-to-parallel conversion used in read operations was supplied by the manufacturer and is mounted in the cassette drive enclosure. The drive control, electronic servo control and command decoding logic was also supplied by ICP and is located in the tape deck. A partial description of these circuits are found in the maintenance and the operations manuals.[7,8] ICP has discontinued manufacture and support of these devices.

Since the existing part of the interface to the tape decks was designed to work with 8-bit bytes of data, the tape format most easily made compatible with DEC software was the binary format used for punched paper tape. With a slight modification, the binary loader used for paper tape handling was converted to handle either punched paper tape or magnetic tape. Likewise, the standard binary punch was also easily modified to handle both magnetic tape and paper tape. A good description of the binary format can be found in DEC-08-LBAA-D, a PDP-8 library document. A checksum system rather than a byte oriented parity check is used for error detection.

The tape cassettes are packaged two decks per unit. Simultaneous reading and writing can be performed on a maximum of one deck per unit at any time. Rewind can be in progress on any deck at any time. There are two device status flags, one per unit. At the completion of a rewind or backspace operation, the unit flag will be set if the deck address is currently set to the deck just rewound. If the other deck is currently addressed, the flag is not set until the deck is addressed. The deck address cannot be changed on a unit during a read or write operation without terminating the operation. At least a 100 millisecond programmed delay must be provided before any command which starts tape forward. Pre-rewind and pre-backspace delays are hard wired.

Execution of the instruction 6122 loads a 4-bit latch in the tape deck interface from bits 0, 1, 2 and 3 in the computer accumulator. Bit 0 specifies the unit address. Bit 1 designates the deck in the unit addressed. Bits 2 and 3 control the rewind and backspace functions respectively. Binary ones in both bits 2 and 3 will result in a rewind.

There are three commands used to write data to tape from bits 4 through 11 of the accumulator. The first is instruction 6121. This instruction causes a program skip if the tape flag for the unit and deck addressed by the address register in the interface is set to logic one. The second command, 6122, is discussed in the preceding paragraph and is used to transfer the tape address and a function code to the address register in the interface. In addition, this command is used to clear the tape flag and the write buffer register. The remaining write command, 6124, clears the tape flag, loads the write buffer from bits 4 through 11 of the accumulator, writes the character to tape and sets the tape flag to indicate that the operation is complete.

If another write command does not occur within 4 milliseconds after the flag has been set for the first write operation, the operation will be terminated, a record gap will be written and the tape transport will stop.

There are three read commands. These commands are supplemented by the command 6122, which as discussed above, is used to clear the tape flag, load the tape command, deck and unit address and clear the write buffer. The first read command, 6111, is used to skip the next program instruction if the tape flag is set for the unit and deck currently addressed. The instruction 6112 reads the read buffer in the interface and clears the tape flag. To clear the tape flag, clear the read buffer, read a character, transfer it to bits 4 through 11 of the accumulator and set the tape flag, one must execute the instruction 6114.

Microprogramming of the three write commands is legal. The combination of 6112 and 6114 in a read command is, however, illegal.

Three error conditions can be detected by the interface any one of which will cause termination of the operation in progress. The condition causing the error can be determined by reading the read buffer (6112) and checking the status of bits 0 and 1 of the computer accumulator. If bit 0 is a one and bit 1 is a zero, an error output from the tape deck currently addressed has occurred. The error output indicates a read error.[9] If bit 0 is a zero and bit 1 is a one, the read switch on the addressed deck is depressed. This prevents computer controlled operation. If both bits 0 and 1 are one, the read or write operation has encountered the end of the tape. It is good practice to check the error bits between each operation if time permits.

Digital-to-Analog Converters

The data acquisition system contains three independent digital-to-analog converters. These converters are CYCON Model 2035, 8-bit converters. They operate at a maximum rate of 50 kHz. A switch on the interface cabinet front panel controls the destination of the converter outputs. The outputs can be switched to three BNC connectors where they are available to drive external

devices such as chart recorders, servo controls, etc. The voltage range is +5 volts to -5 volts in this mode. The second switch position connects the converter outputs to a Hewlett-Packard Model 7005B X-Y Recorder which has been modified to allow remote operation of the pen up/down control. In this application the voltage ranges from +5 volts to -5 volts on the X and Y-axes and from 0 to +10 volts on the Z-axis. The third function of the D/A converters is in driving a small CRT display. Two converters apply voltages ranging between +5 volts and -5 volts to the X and Y deflection amplifiers in a modified Tektronix Model 602 CRT display. The third converter applies voltages ranging between 0 and +10 volts to the CRT Z-axis.

Each converter is buffered by an 8-bit latch which is loaded from bits 4 through 11 of the accumulator. The X-axis converter is loaded by the instruction 6501. The Y-axis converter is loaded by the instruction 6502. The command 6504 is used to load the Z-axis converter. These instructions could be microprogrammed in any desired combination.

Computer-controlled Trigger Pulses

A general purpose interface was built into the data acquisition system to provide a means of triggering external devices on computer command. This interface provides three instructions for this purpose.

The first instruction 6541 results in pulses on four different lines. Two pulses are 500 nanoseconds long, one is a positive pulse from 0.2 volt to 4.5 volts. The second short pulse is a transition from 4.5 volts to 0.2 volt and back to 4.5 volts. The second pair of pulses which result from the instruction 6541 are 1 millisecond long and start at the same time as the 500 nanosecond pulses. One of these two pulses ranges from ground potential to +15 volts and the second is a negative pulse ranging between ground potential and -15 volts.

The second instruction, 6542, causes a positive TTL pulse to appear on one external connector and a negative TTL pulse to appear on a second line. Both pulses are 500 nanoseconds long.

The third command is 6544. Positive and negative TTL pulses of 500 nanosecond duration appear on separate connectors as a result of the execution of this instruction.

All of the short pulses are buffered IOP's. Therefore, microprogramming will result in the initiation of pulses on all lines with a fixed time relation for their leading edges within a single 4.8 microsecond expanded computer cycle time.

External Computer Interrupt Control

In data acquisition applications, it is frequently desirable to initiate a sequence of computer program steps at a time based on the occurrence of an event external to the computer. A program interrupt facility is provided in most computers to allow a pulse from an external source to "interrupt" the program in progress and cause a new sequence to begin. Such a facility is usually shared with one or more peripheral devices. When multiple connections are made to the interrupt bus, the programmer must provide software to enable the computer to determine which device caused the interrupt and requires servicing. This is normally accomplished by checking device status flags. The order in which the status flags are checked provides an interrupt priority hierarchy. If, however, the program in progress has the highest priority, all interrupts may be locked out by executing a computer instruction, 6002. The command 6001 is used to enable external interrupts.

In the application for which the system to be described was designed, a sequence of program steps was to be initiated at a predetermined time after each of a sequence of underwater explosions. Since the explosive was detonated

by a fuse rather than electrically, there was no accurate way of controlling the time of the explosion. Therefore, explosions were sensed by a hydrophone which was positioned at a known distance from the point of the explosion. The signal appearing at the hydrophone output was a combination of ambient sea noise, own-ship's noise and the signal from the explosion. With this combination of signal and noise, there was a finite probability of interrupting the computer on the basis of noise alone rather than signal plus noise. Since the software used in the data acquisition process required that the interrupt be enabled at all times in order that the computer should be accessible through the teletype, the internal interrupt enabling and disabling features could not be used to exclude noise caused interrupts at critical times.

Two features were added to the existing interrupt facility in order to reduce the probability of noise related interrupts. The first was a variable threshold. This device consists of a series combination of a variable gain (X1 to X10) amplifier with a dc bias control and a Schmitt trigger. The amplifier is a standard 741 operational amplifier wired in inverting mode. The Schmitt trigger is a standard TTL circuit on a single chip. The existing circuit was designed to provide a negative voltage threshold. Thus, the interrupt circuit is triggered by a negative pulse at its input.

The circuitry for the portion of the interrupt circuit external to the computer is located in the main interface cabinet. The input, threshold control and a monitor for the threshold circuit output are located on the interface cabinet front panel.

The second feature added to the existing interrupt facility was a provision to enable or disable the line from the threshold circuit to the computer interrupt bus. This logic allowed interrupts from the hydrophone to be accepted or ignored under program control without disabling the computer interrupt bus and without requiring the computer to service all interrupts, discarding those from the hydrophone.

To enable the hydrophone interrupt channel, the instruction 6442 was implemented. The command 6444 clears the hydrophone interrupt flag and disables the interrupt channel. The instruction 6441 is used to test the device flag. A program skip results if the flag is set to logic one.

Shipboard Sonar Systems

Two research sonars are available on the R/V DAVID STARR JORDAN. One operates at a center frequency of 11 kHz and the other at 29.8 kHz. An echo sounder, operating at 18 kHz is also available. All three instruments were manufactured by SIMRAD. The echo sounder is Model EH-3 and the sonars are designated Model 580-10.

The 30 kHz (29.8 kHz) sonar can be trained through 360° in aximuth and from approximately +20° to -90° in depression. The 11 kHz sonar can be steered to any azimuth but cannot be depressed. Echo sounding modes are available on both instruments. In normal applications, both sonars use short CW pulses of maximum 80 millisecond duration. Signal processing is severely limited, including reverberation controlled gain or time varied gain and simple bandpass filtering. A CRT display and wet paper recording are provided as primary displays. Both suffer limited resolution and dynamic range.

During the conduct of the research, transmit and receive beam patterns were measured at the U. S. Navy Electronics Laboratory Sensor Accuracy Check Site in the Long Beach Naval Shipyard. Receiving sensitivity and transmit beam patterns are illustrated in Figures 1 through 4 for both sonar systems.

Complete information on the sonars and the echo sounder operations and maintenance are available in SIMRAD manuals.

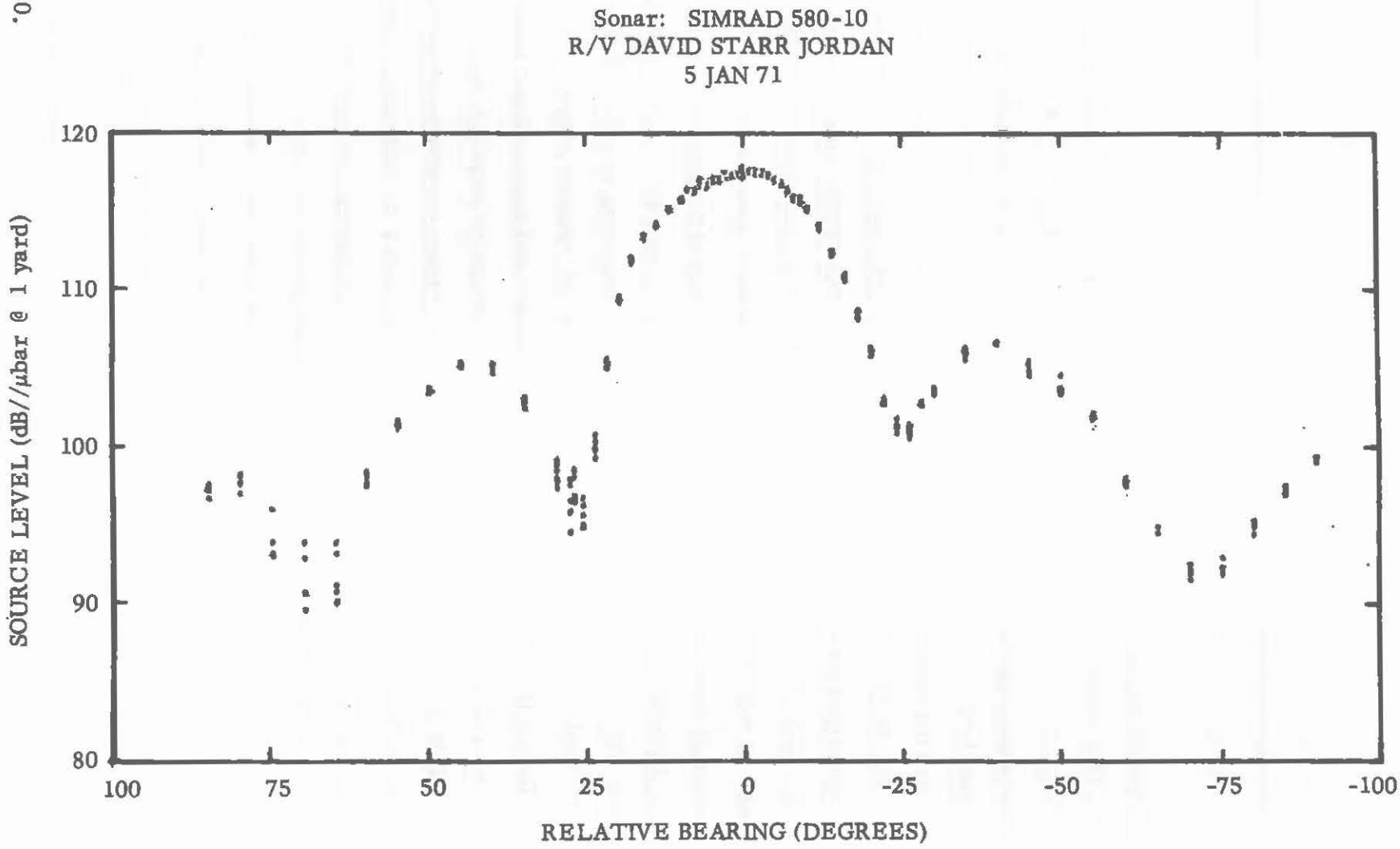

Figure 1. TRANSMIT BEAM PATTERN (11 kHz)
(HORIZONTAL)

Sonar: SIMRAD Model 580-10
R/V DAVID STARR JORDAN
5 JAN 71

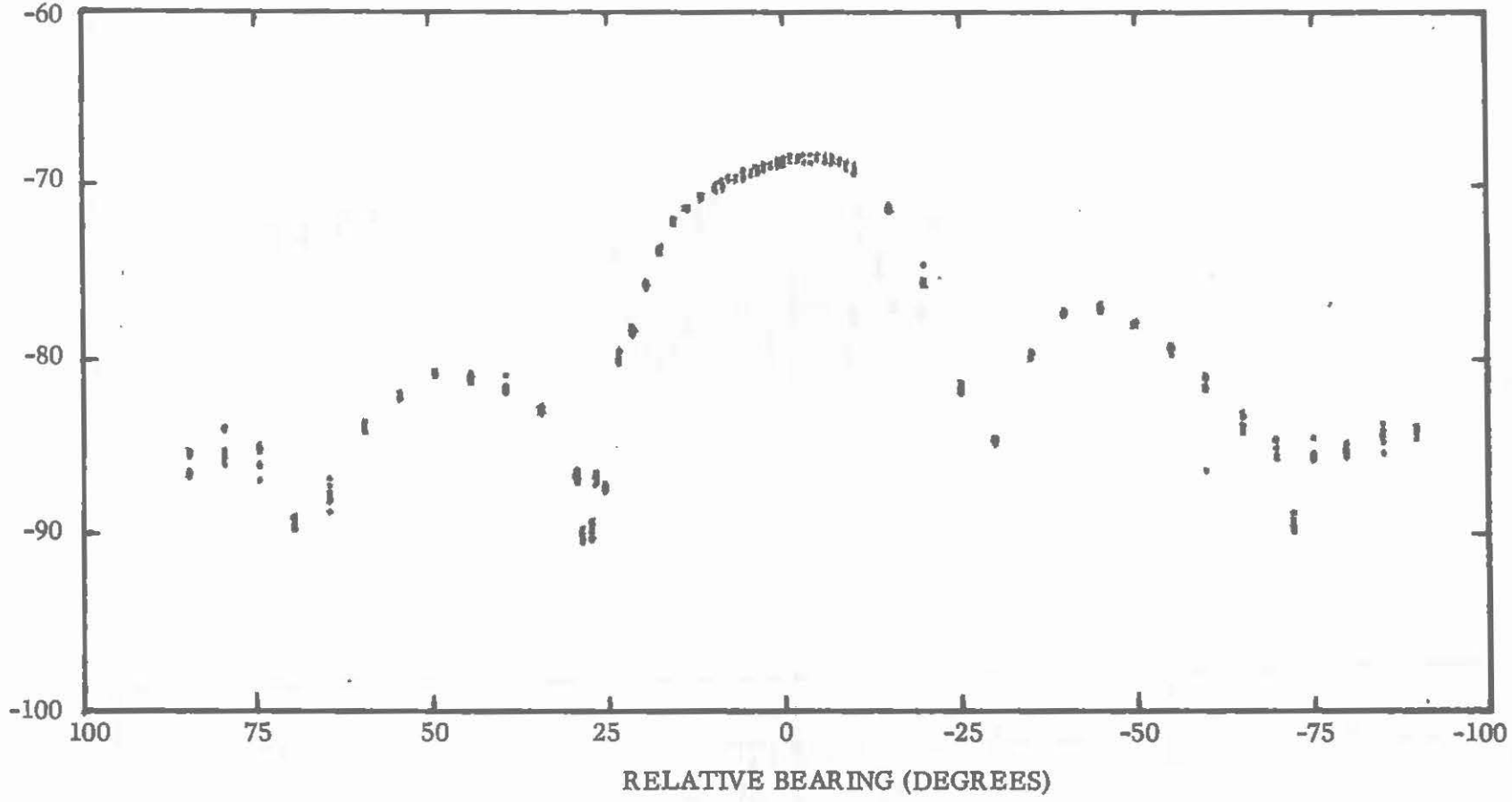

Figure 2. RECEIVE BEAM PATTERN (11 kHz)
(HORIZONTAL)

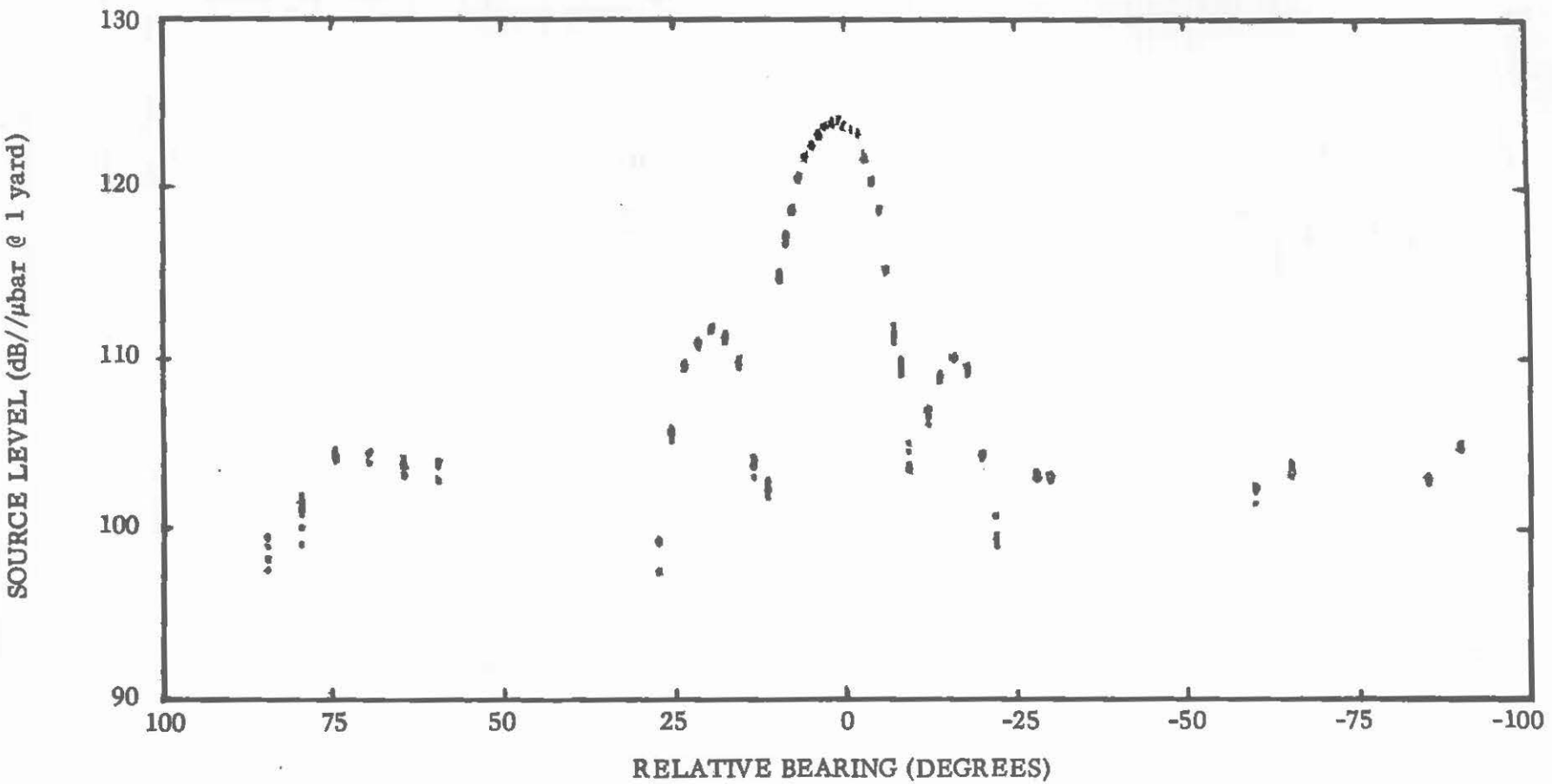

Figure 3. TRANSMIT BEAM PATTERN (30 kHz, Narrow Beam Width)
(HORIZONTAL)

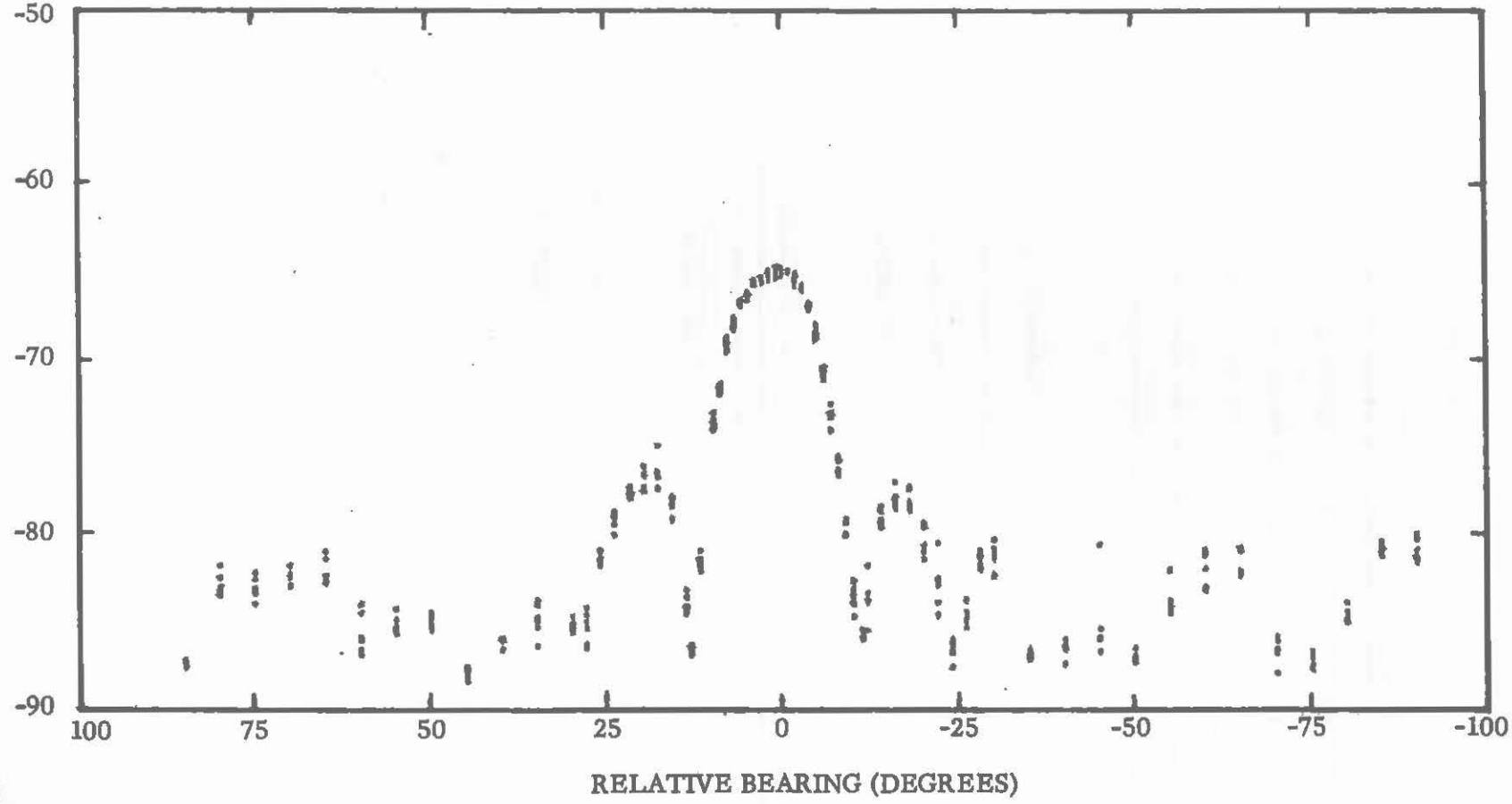

Figure 4. RECEIVE BEAM PATTERN (30 kHz)
(HORIZONTAL)

III. SOFTWARE

Since ship time is a valuable, expensive commodity in an oceanographic research program, the flexibility to change a data acquisition process at sea in a matter of minutes can be an extremely valuable part of such a research program. This is particularly the case when the duration and number of sea trips is limited and many of the environmental and experimental situations to be encountered are predictable to only an order-of-magnitude or sometimes less accuracy.

In the light of these considerations, the software developed and used in the sea tests was an interpretive language based partially on the Digital Equipment Corporation FOCAL®. After substantial modification and expansion an executive system (EXEC) with the required flexibility for at-sea data acquisition resulted.

The retention and expansion of FOCAL's capability for performing on-line or programmed scientific calculations from an interactive, high-level language was a secondary but valuable consideration in the development of EXEC.

The decision to make the executive software a high-level, interactive, interpretive software system was strongly influenced by limitations of the sonar system which were not readily changed. Since both sonar systems were designed for a maximum 80 millisecond pulse duration, the pulse repetition rate was necessarily slowed substantially to allow use of longer pulses. This was done to prevent serious damage to the transmitter. The extended pulse repetition rate limited the sonar data rate rather than the speed at which the computer could acquire and process the acoustic data. If the equipment limitations had not been present, a trade-off between the speed of an efficient machine-language code and the slower interpretive software would have been necessary. Since changes at the machine language level would have required days as opposed to minutes

for the interpretive language, hindsight indicates that the ship time required to perform the same work might have been doubled if the machine language approach had been chosen.

Listings of the modifications to FOCAL-69® (DEC-08-AJAE) with the 8K-overlay and the MODV overlay follow.[11, 12] For those additions to FOCAL which are in the form of functions, a brief description of the function performed and of the call format are presented. Finally, a complete core dump after execution of the initial dialogue with FOCAL and the secondary dialogue with EXEC is presented in Appendix I. A core map is given in Appendix II. Appendix III contains a listing of WTBIN. This is a utility routine for writing blocks of data to the magnetic tape cassettes in binary format. Loading and operating instructions are provided in Appendix IV. Instructions for expanding available program and data space at the expense of several external devices is also provided in Appendix IV. The service routine RTBIN is used to read blocks of binary data from either paper tape reader or the magnetic tape cassettes. A listing and operating instructions are provided in Appendix V.

A. Miscellaneous Patches

Several patches were required to correct problems with either FOCAL-69 or MODV. Corrections, text overlays, and several housekeeping patches follow. The patches beginning in 0 3206 and 0 3260 are destroyed by the initial dialogues. The patches at 0 0004 and 1 3511 are discussed further in Appendix IV as are the patches at 0 0060, 0 0135 and 1 0007.

Text Overlay

```
*3206
        3217
        0000
        0355
        0530
        0503
        5567
        6255
        6061
        7715
*3260
        4705
        3005
        0355
        6762
        5560
        6147
$
```

Patch to MODV

```
FIELD 1
*3412
        0045
        7045
        4315
        2722
        1520
        2100
        5557
        4400
        2077
FIELD 0
$
```

```
FIELD  0
LINE1=400

*4374       /TURNS OFF CRT AFTER INIT DIALOG
 6504
*60         /RESET LINE1
 LINE1
*135
 LINE1
FIELD 1

*7
 LINE1
$
```

```
FIELD 1
*104     /TEXT PATCH
4005
3005
0355
6762
5560
6140
*3511    /LAST ADDRESS NOT PROTECTED IN FIELD 1
6444
FIELD 0
*4       /ANOTHER PLACE TO PATCH LAST ADDRESS NOT PROTECTED
6444     /IN FIELD 1
*6002    /PATCH TO SUPPRESS = ON OUTPUT
7200
*5333    /PATCH TO ONE OF THE SINE CONSTANTS
2501
*2652    /REMOVE A BUG IN FOCAL WHICH INTEFERES WITH FIELD 1
6101     /CODING
7000
1201
7104
1200
6244
$
```

B. Multi-use Argument Fetch Subroutine

This routine is used by any function which requires one or more arguments from the program being executed. It is normally called from GETARG.

```
/ EXEC-72-01  FETCH CHARACTER ROUTINE
*1532
MCOMMA, -254
*1553
ARG,    TAD     CHAR    /CODING TO FETCH NEXT CHAR
        TAD     MCOMMA  /RETURN TO CALL+3(CALL+2)
        SZA CLA         /IF CHAR IS (IS NOT) A COMMA
        JMP     .+4
        PUSHJ
        EVAL-1
        IAC
        POPJ
CHAR=66
PUSHJ=4540
EVAL=1613
POPJ=5541

$
```

C. Library Command Processor

This processor is used to expand the command structure of FOCAL-69.

The format of all library commands is L X Y. L is the library command designator. X is the sub-command designator. X may be multiple letters and is terminated by a space. Only the first letter is used and the remaining characters may be deleted thereby saving program space. Y is the argument or arguments for the command. The arguments follow the standard FOCAL[13, 14] format and may be subscripted.

The library processor is expandable by three more functions. The ASCII code for the sub-command must be inserted into the array CLIST. The corresponding slot in the array GOLIST must be filled by the entry address for the routine which executes the desired command.

Two new commands have been implemented. The first is a command to punch data in ASCII format on the high speed punch. The command performs the same function with output to the high speed punch as the command TYPE in FOCAL. To punch data on the high speed punch, execute the command L P DATA1, DATA2, etc.

The second command allows listings to be made on the high speed punch rather than on the low speed punch or the teletype. This command supplements the FOCAL commands WRITE and WRITE ALL. To list or produce a program tape in ASCII code which is suitable for reading under the FOCAL command *, execute the command L W ARGUMENT. ARGUMENT may be a line number, a group number or if it is missing the entire program will be output on the high speed punch. No leader is punched by the program, therefore it must be manually punched if desired.

```
                                        FIELD 0
/LIBRARY COMMAND PROCESSOR

*COMGO+10
        LIBRAR
*7503
LIBRAR, SPNOR                   /IGNORE SPACES
        TAD     CHAR            /GET NEW COMMAND CHAR
        PUSHA                   /STASH IT
        GETC                    /GET NEXT
        SORTC                   /MOVE TO TERMINATOR
         GLIST-1
         SKP
         JMP    .-4
        SPNOR                   /IGNORE SPACES
        POPA                    /GET NEW COMMAND CHAR BACK
        SORTJ                   /GO THERE
         CLIST-1
         GOLIST-CLIST
        ERROR                   /NOT IN LIST
CLIST,  320                     /PUNCH
        327                     /WRITE TO HI SPEED PUNCH
        0
        0
        0
        0
        7777                    /LIST TERMINATOR
GOLIST, 0                       /PUNCH ADDRESS
        0                       /WRITE ON HSP ADDRESS
        0
        0
        0
        0
SORTC=4550
GLIST=1377
SPNOR=4560
PUSHA=4542
GETC=4545
POPA=1413
SORTJ=4547
ERROR=4566
CHAR=66
COMGO=1163
$
```

D. High Speed Punch and Write Processors

The formats and syntax for these routines are discussed in Section C immediately preceding this section.

```
/LIBRARY PROCESSOR FOR HI SPEED PUNCH AND WRITE COMMANDS
FIELD 0
*BOTTOM
        INTPR-1
*4060-151-14
INTPR,  PSF
        JMP     EXTINT
        PCF
EXTINT, JMS     SERVP
        JMP  I  RETNP
RETNP,  2654
SERVP,  0
        NOP                     /ROOM FOR JMS I TO SERVICE
        NOP                     /TWO UNSPECIFIED INTERRUPTS
        JMP  I  SERVP
        0                       /DEVICE SERVICE ROUTINE ADDRESSES
        0
*CLIST
        320
        327
*COLIST
        PUN
        HSW
*2652
        5653
        INTPR
*4060-151
HSW,    CLA CMA                 /SET UP TYPE OF WRITE ? SWITCH
        DCA     SW
PUN,    CLA
        TAD     TELSW
        SZA
        JMP     .-2
        IOF
        TAD     IN1
        DCA     63
        TAD     IN2
        DCA     64
        TAD     IN3
        DCA  I  PT31
        TAD     IN4
        DCA  I  PT41
        TAD     IN5
        DCA  I  PT51
        TAD     IN4
        DCA  I  PT101
        ISZ     SW
        JMP     TYP
        TAD     IN6             /INTERCEPT RETURN FROM WRITE
        DCA  I  PT61
        TAD     IN7
```

```
        DCA   I   PT61+1
        JMP   I   WHITE
TYP,    TAD       IN8
        DCA   I   PT81
        TAD       IN9
        DCA   I   PT81+1
        JMP   I   TYPE
PT31,   8738
PT41,   8762
PT51,   1357
PT61,   671
        672
PT11,   1577
        1600
PT101,  1355
WHITE,  635
TYPE,   1203
IN1,    1354
IN2,    8414
IN3,    5336
IN4,    7900
IN5,    6021
IN6,    5678
IN7,    ENDW
IN8,    ENDT1
IN9,    ENDT2
ENDT1,  TAD       M4
ENDT2,  TAD       I9
        JMP       X
        PAGE


X,      DCA       NAD
        TAD       R8
        DCA   I   PT8
        TAD       R9
        DCA   I   PT8+1
        JMP       FIN
ENDW,   TAD       R9
        DCA       NAD
        3886
        TAD       R6
        DCA   I   PT6
        TAD       R7
        DCA   I   PT6+1
FIN,    TAD       R1
        DCA       63
        TAD       R2
```

best scan possible

```
            DCA       64
            TAD       R3
            DCA   I   PT3
            TAD       R4
            DCA   I   PT4
            TAD       R5
            DCA   I   PT5
            TAD       R4
            DCA   I   PT10
            DCA       SW
            ION
            JMP   I   NAD
M4,         -4
NAD,        0
SW,         0
R1,         2676
R2,         2666
R3,         6001
R4,         6046
R5,         6041
R6,         3026
R7,         5541
R8,         610
R9,         614
PT3,        2722
PT4,        2772
PT5,        1357
PT6,        671
            672
PT8,        1577
            1600
PT10,       1355
BOTTOM=35
CLIST=7521
GOLIST=7530
TTLSW=16
```

E. I/O Pulse Processor

This routine controls the application of pulses to several connectors on the front panel of the interface cabinet from a high-level language. Implemented as a FOCAL function, the software call S A = FIOP(X) will cause a pulse at the connector designated by X. The character A is a dummy variable. The variable X may be alphabetic, representing a previously defined decimal value or may be a decimal number. In either case, the value of X is converted to octal, placed in the function routine as in-line code and is executed as an instruction.

The three basic machine language commands which control the computer-controlled trigger pulse interface are discussed in the hardware description, Section II of this memo. They are 6541, 6542 and 6544. Their decimal equivalents are 3425, 3426 and 3428 respectively. Thus, executing the instruction S A = FIOP(3425) will cause the pulses described in Section II to appear at the BNC connectors so labelled on the interface cabinet front panel.

Since any single machine language instruction can be executed from EXEC level with this function, the function also finds a use in executing such commands as set transient hold, step spectrum analyzer address, erase spectrum averager, etc.

Some caution should be exercised in executing the function FIOP since jumps and core modifications which could modify any part of core (except that which is hardware protected) including EXEC are possible.

```
FIELD 0
FNTABL=2165
EFUN3I=136
INTEGER=53
FNTAB=374
*FNTABL+4
        2622
START=1343
*FNTAB+4
        XIOP
*START
XIOP,   DCA     TAC     /SAVE AC
        JMS  I  INTEGER /MAKE FLARG AN INTEGER
        DCA     INSTR   /DEPOSIT INSTRUCTION IN-LINE
        TAD     TAC     /RESET AC
INSTR,  0
        CLA             /CLEAR AC FOR RETURN
        JMP  I  EFUN3I  /RETURN
TAC,    0
$
```

F. Analog-to-Digital Converter Routine

This routine was designed to service the A/D converter. The A/D converter routine is named XADC and includes a multiplexer channel select feature. The call S A = FADC(CH) sets the variable A equal to a digital decimal value representing the voltage at the CH-th input of the analog multiplexer. The channel designator CH may take on any integer value from 0 through 7. The variable A may be subscripted.

The range of the input voltage is controlled by a switch on the interface cabinet front panel rather than by software. For symmetric ranges of input voltage (±5, ±10 volts) the binary number representing the largest positive voltage is 3777 and the number representing the largest negative voltage is 7777. Zero voltage at the input results in a 0000. When the input switch is set to the 0 to +10 volt range, the digital output ranges from 0000 to 7777.

A voltage at the A/D converter input which exceeds the range set by the hardware switch will result in a zero value for A. The multiplexer cannot be used for negative voltages larger than -5 volts. The A/D converter must be connected directly to the source voltage for cases in which the source voltage will exceed this limit.

```
/ANALOG-TO-DIGITAL CONVERTER ROUTINE
/CALL: S X=FADC(CH)
/CH IS THE ANALOG MULTIPLEXER CHANNEL NUMBER
/X IS SET EQUAL TO THE CONVERTER OUTPUT VALUE

FIELD 0
*BOTTOM
        XADC=1


START=4315
*FNTABF+5
        XADC
*START
XADC,   JMS  I  INTEGER /MAKE AN INTEGER OF CHANNEL NUMBER
        6511            /SELECT CHANNEL
        6773            /CLEAR FLAG AND SAMPLE
        6102            /SKIP ON READY WITH SAMPLE
        JMP     .-1     /NOT READY, TRY AGAIN
        6774            /TRANSFER NUMBER TO AC
        CLL RAR         /CHECK FOR '-0'
        DCA     FLAC+1
        RAR
        DCA     FLAC+2
        TAD     C14
        DCA     FLAC
        JMP  I  EFUN3I  /CHECK FOR RIGHT PAREN, NORMALIZE FLAC,
                        /AND RETURN
C14,    14
FLAC=44
EFUN3I=136
INTEGER=53
FNTABF=374
BOTTOM=35
$
```

G. External Interrupt Service Routine

Both FOCAL and EXEC run with the computer interrupt on. This allows interaction with the computer through any external device at any time, e.g., input via the teletype. At each occurrence of an external interrupt a sequence of software checks is performed to determine the source of the interrupt and to service the device causing the interrupt.

The listing which follows is a routine which sets location 3420 base 8 (1808 base 10) in field 0 to one if the interrupt resulted from a signal at the external interrupt connector on the interface cabinet front panel.

Clearing the interrupt flag is the responsibility of EXEC level software. This flag maintenance is generally performed by calling the function FRAW. The call S A = FRAW (0, 1808, 0) will deposit a zero in the location of the software interrupt flag.

```
          /MODIFY TOP OF PDL LOCN

FIELD 0
END=134
*END
         7553


/ROUTINE TO SERVICE EXTERNAL INTERRUPTS
/
/SOFTWARE INTERRUPT FLAG IS IN 3420 BASE 8 (1808 BASE 10)
/
/CLEARING SOFTWARE INTERRUPT FLAG IS EXEC LEVEL
/RESPONSIBILITY
/
/
FIELD 0
*3702
         JMS  I  .+3
*3705
         SERVEX
SERVP=3701
START=3411
*START
SERVEX, 0
         6441              /SKIP IF INTERRUPT FLAG IS SET
         JMP  I  SERVEX    /RETURN TO SERVICE MORE DEVICE(S)
         IAC
         DCA     INTFLG    /SET INT FLG = 1 IF HARDWARE FLAG =1
         6444              /CLEAR HARDWARE FLAG AND LOCK OUT
         JMP  I  SERVEX    /MORE EXTERNAL INTERRUPTS
INTFLG, 0                  /SOFTWARE INT FLAG (1807 BASE 10)
$
```

H. Absolute Address Read and Write Routine

One disadvantage of a high-level, algebraic language such as FOCAL is the absence of a mechanism for manipulating data in absolute addresses in core. The software routine XRAW allows the contents of an absolute location in either field 0 or field 1 to be read from core or written into core by an EXEC level command.

While there is the disadvantage that this process is slow and can result in modification of EXEC itself if misused, there is a substantial advantage in such uses as clearing software flags, setting up arrays for display on the CRT or Ross hard-copy recorder. The routine can also be used to conserve storage by storing such data as can be so represented in single word, fixed point data arrays.

To set the floating point variable A equal to the value XXXX in field Y, execute the EXEC command S A = FRAW(Y, XXXX). The argument XXXX is the decimal value of the absolute octal address or is an appropriate algebraic expression used to compute the address in decimal.

To set the location XXXX in field Y equal to the octal, fixed point value of the variable B, one may execute the command S A = FRAW(Y, XXXX, B). The variable A is a dummy variable. The variable B may be a number of a non-subscripted variable or a subscripted variable.

```
/FRAW: READ AND WRITE ABSOLUTE ADDRESSES


/WRITE: S  Y=FRAW(A,L,X) ; X TO (A,L) AND Y
/A IS THE DATA FIELD , L IS THE CORE LOCATION IN DECIMAL
/AND X IS THE EXEC VARIABLE TO BE FIXED IN INTEGER FORMAT
/AND WRITTEN TO CORE.  Y ALSO CONTAINS X ON RETURN.

/READ: S  Y=FRAW(A,L) ;  (A,L) TO Y.
/A IS THE DATA FIELD, L IS THE REQUIRED ABSOLUTE LOCATION IN
/DECIMAL.  THE ROUTINE SETS Y=CONTENTS OF (A,L).
FIELD 0
START=4227
*BOTTOM
        KOUNT-1
*FNTAB+14
        XRAW
*FNTABL+14
        2641
*START
KOUNT,  0
XRAW,   TAD     PFLD
        DCA     ACTR    /PUT LIST ADDRESS IN ACTR
        DCA     KOUNT   /CLEAR ARGUMENT COUNTER
LOOP,   ISZ     KOUNT   /INCREMENT AND SKIP ON ZERO
        JMS  I  INTEGER /FETCH NEXT ARG
        DCA  I  ACTR    /STORE IN LIST
        TAD     ACTR
        IAC
        DCA     ACTR
        PUSHJ
        ARG             /GET NEXT CHAR
        SKP             /NOT A COMMA
        JMP     LOOP    /RETURN IF COMMA ;NEXT ARG IN FLAC
        CLL CLA
        TAD     FLD     /SET UP FIELD CHANGE COMMANDS
        RTL             /POSITION FIELD BIT
        RAL
        TAD     FINST
        DCA     RFCH
        TAD     RFCH
        DCA     WFCH
        TAD     KOUNT   /CHECK FOR 2 ARGS
        TAD     M2
        SZA             /SKIP IF READ
        JMP     CNTTST  /JUMP TO CONTINUE TEST
```

```
RFCH,   0                       /CHANGE DATA FIELD
        TAD  I  LOCN            /GET WORD
        CDF     0               /SET DF=0
        JMP     EXIT
CNTTST, TAD     M1
        SZA CLA
        ERROR                   /INCORRECT NO OF ARGS
WRITE,  TAD     CNTS            /CALL IS FOR A WRITE
WFCH,   0                       /INSTRUCTION TO SET DATA FIELD
        DCA  I  LOCN            /WRITE CNTS TO LOCN
        CDF     0               /SET DF=0
        TAD     CNTS
EXIT,   CLL RAR                 /PREPARE TO EXIT
        DCA     FLAC+1
        RAR
        DCA     FLAC+2
        TAD     C14
        DCA     FLAC
EX,     JMP  I  EFUN3I          /EXIT
ACTR,   0
PFLD,   FLD
FLD,    0
LOCN,   0
CNTS,   0
M2,     -2
C14,    14
FINST,  CDF     0
M1,     -1
PUSHJ=4540
INTEGER=53
BOTTOM=35
FLAC=44
ARG=1553
EFUN3I=136
ERROR=4566
FNTAB=374
FNTABL=2165
$
```

I. A Multi-function Routine

The function table in FOCAL-69 is limited to 15 entries. To remove this limitation in a direct manner would require a recompilation from the assembly language level. To reassemble the program would require punching the assembly code onto tape or cards and assembly on a machine with more storage than the PDP-8/L.

The limitation of 15 table entries can also be removed by expanding one of the entries into a general purpose routine which can perform several functions depending on the arguments in the function call. This approach was adopted for the data acquisition software. The general purpose routine XGEN allows an expansion in the number of functions which is limited only by the memory available to implement the functions. Three functions have been implemented in this manner.

The FOCAL function FSGN was deleted and replaced by a function to drive the spectrum analyzer. This was done to shorten the time required to call and execute the spectrum analyzer routine. The spectrum analyzer routine was called much more frequently than FSGN, the sign function, and a significant savings in execution time resulted. Although the call FSGN is no longer available in EXEC, the function for obtaining the sign of a number is available through the call S A = FGEN (ØSGN, N). The variable A is set to the value of the sign (±1) of the variable N. The characters SGN are prefixed with a zero.

A time delay function was added to FOCAL for use in the control of time sequenced events. The time delay is initiated at the time the function is called. Time (T) is in units of 0.1 millisecond. At the end of the time delay, a single instruction, PLSINS, is executed. This instruction, the decimal representation of the octal code, is usually an instruction which produces a command for some external device. The call, S A = FGEN (ØTDL, T, PLSINS) is through the general function XGEN. The variable A is a dummy variable.

In some situations, one may desire to start a time delay based on the occurrence of an event external to the computer, e.g., the detonation of an explosive sound source. The call S A = FGEN(ØWAT, T, PLSINS) initiates a tight software loop in which the computer repeatedly checks the software interrupt flag. The time delay is initiated when the software interrupt flag is set to one indicating an external interrupt through the connector on the front panel of the interface cabinet. At the end of the time delay (T in units of 100 microseconds) the octal representation of the decimal value of PLSINS is executed as a machine language instruction. The external interrupt interface hardware is enabled at the time of entry into XGEN/ØWAT. The external interrupt software flag (3420 base 8) is cleared by the software in XGEN/ØWAT after it is set by the external interrupt service routine but prior to the time the time delay is initiated.

```
/GENERAL SUBROUTINE

/CALL: FGEN(ØSGN,N)

/CALL: FGEN(ØTDL,T,PLSINS)

/CALL: FGEN(ØWAT,T,PLSINS)


FIELD Ø
*FNTABL+15
        2564
*FNTABF+15
        XGEN
*3374
XSGNE,  CDF     Ø
        JMP  I  XSGNP
XSGNP,  XSGN
*7500
XGEN,   CIF     1Ø
        JMP  I  XGEN1P
XGEN1P, XGEN1
*1142
GETARG, Ø
        CDF     Ø
        PUSHJ
        ARG
        JMP     NC      /NOT COMMA
        CLA CLL IAC RAL /COMMA
        TAD     GETARG
        DCA     GETARG
        CIF     1Ø
        JMP  I  GETARG  /COMMA,GO BACK TO CALL+3
NC,     CIF     1Ø
        JMP  I  GETARG  /NOT COMMA,GO BACK TO CALL+1
*3421
INTF1,  Ø
        CDF     Ø
        JMS  I  INTEGER
        CIF     1Ø
        JMP  I  INTF1
```

```
FIELD   1
*113
2726                    /ADDRESS OF ERROR EXIT IN FIELD  0
2017                    /ADDRESS OF FUNCTION RETURN IN FIELD 0
INTF1P, INTF1
GETARP, GETARG
SMPDLP, SMPDLY
CTIMH,  0
CTIML,  0
INSTR,  0
*200
XGEN1,  CDF     0
        TAD  I  FLARGL
        TAD     CTDLL
        SZA CLA
        JMP     NEXT1
        TAD  I  FLARGH
        TAD     CTDLH
        SNA CLA
        JMP     XTDL    /IS TDL
NEXT1,  TAD  I  FLARGL
        TAD     CSGNL
        SZA CLA
        JMP     NEXT2
        TAD  I  FLARGH
        TAD     CSGNH
        SZA CLA
        JMP     NEXT2
        CIF     0
        JMS  I  GETARP  /IS SGN
ERR,    CIF     0       /NOT A COMMA
        ERROR1          /INCORRECT NO ARGS (ALSO USED
                        /BY KK BELOW)
        CDF     10      /COMMA
        CIF     0
        JMS  I  INTF1P
        CIF     0
        JMP  I  PXSGNE
NEXT2,  JMP  I  WAITP
WAITP,  WAIT
XTDL,   CIF     0
        JMS  I  GETARP  /GET TIME PARAMETER
        CIF     0       /NOT A COMMA
        ERROR1          /NOT ENOUGH ARGS
        CIF     0       /IS A COMMA
        JMS  I  INTF1P
```

```
          DCA      CTIML
          TAD  I   FLACHP
          DCA      CTIMH
          TAD  I   FLACEP
          TAD      M30
          SZA
          JMP      TESTG    /EXP NOT 30
          TAD      CTIML    /EXP = 30, ROTATE ALL LEFT ONE
          CLL RAL
          DCA      CTIML
          RAL
          TAD      CTIMH
          CLL RAL
          DCA      CTIMH
TESTG,    SPA SNA CLA       /SKIP ON > 0
          JMP      GOON     /OK,<30
          CIF      0        /FLAC>30;ARG TOO BIG
          CDF      0
          ERROR1
GOON,     TAD      INSTP    /LIST ADDR TO CTR
          DCA      ACTR
          DCA      KOUNT    /CLEAR KOUNT
M0,       ISZ      KOUNT
          CIF      0
          JMS  I   GETARP   /GET AN ARG
          NOP               /NOT A COMMA,THIS IS A SPACER
          JMP      KK
          CIF      0        /IS COMMA
          JMS  I   INTF1P
          CDF      10
          DCA  I   ACTR     /STORE IN LIST
          TAD      ACTR
          IAC
          DCA      ACTR     /INCR ACTR
          JMP      M0
KK,       TAD      M2       /ALL ARGS IN NOW
          TAD      KOUNT
          SZA CLA
          JMP      ERR      /INCORRECT NO ARGS
          CDF      10
          ISZ  I   FLGWP
          JMP      ENTER
          JMP  I   WLOOPP
WLOOPP,   WLOOP
FLGWP,    FLGW
M2,       -2
PXSGNE,    XSGNE
FLACLP,   46
```

```
INSTP,   INSTR
FLACHP,  45
FLACEP,  44
M30,     -30
KOUNT,   0
ACTR,    0
FLARGH,  2030
FLARGL,  2031
CSGNH,   -0013
CSGNL,   -3700
CTDLH,   -0014
CTDLL,   -2002
ARG=1553
PUSHJ=4540
FNTABL=2165
FNTABF=374
ERROR1=4513              /FIELD 1 ERROR RETURN INSTR
XSGN=2010
INTEGER=53
ENTER,   CLA CLL
         TAD     CTIML
         CMA
         DCA CTIML
         RAL
         TAD CTIMH
         CMA
         DCA CTIMH
LOOP,    JMS SMPDLY      /ABOUT 100 USEC
         ISZ CTIML
         JMP LOOP
         ISZ CTIMH
         JMP LOOP
         TAD INSTR
         DCA INS
INS,     0
         CLA CLL
         DCA  I   FLGWP   /CLEAR WAIT FLAG
         CDF 0
         CIF 0
         JMP I EFUN31
SMPDLY,  0
         TAD NUMLUP
         DCA COUNT1
         ISZ COUNT1
         JMP .-1
         NOP
         JMP I SMPDLY
DECIMAL
```

```
COUNT1, 0
OCTAL
NUMLUP, 7761
EFUN31=114
ERROR1=4513
PAGE
WAIT,    TAD  I   FLRGLP
         TAD      CWATL
         SZA CLA
         JMP      NEXT3
         TAD  I   FLRGHP
         TAD      CWATH
         SNA CLA
         JMP      WAITL    /IS WAIT CALL
NEXT3,   CIF      0
         ERROR1             /NOT AN FGEN CALL
WAITL,   CDF      10
         CMA
         DCA      FLGW     /SET FLGW = -1
         JMP  I   XTDLP
WLOOP,   CDF      0
         6442               /ENABLE EXT INTERRUPT
         TAD  I   INTFG    /GET INTERRUPT FLAG
         SNA CLA
         JMP      .-2
         DCA  I   INTFG
         CDF      10
         JMP  I   ENTERP   /GO DO TIME DELAY
FLRGLP, 2031
FLRGHP, 2030
ENTERP, ENTER
INTFG,  3420
XTDLP,  XTDL
CWATL,  -2215
CWATH,  -0014
FLGW,   0
FIELD 0
*60
FLGW+1
*135
FLGW+1

FIELD 1
*7
FLGW+1

FIELD 0
$
```

J. The Spectrum Analyzer/Averager Software

The spectrum analyzer and spectrum averager are serviced by a combination of the routines XIOP, XGEN/ØTDL, XGEN/ØWAT and XSPA. Any of of the first three routines can be used to set and release the transient capture feature of the analyzer. The routine XSPA is used to erase the averager, perform a new average and to digitize the spectrum from either the spectrum analyzer or the averager and transfer the spectra to core memory in the computer.

The spectrum averager is erased by performing the EXEC instruction S A = FSPA(0). The character A is a dummy variable.

The spectrum averager is commanded to perform an average by the instruction S A = FSPA(1). The character A is a dummy variable.

The command S A = FSPA(CH, L, XXXX) is used to step the analyzer or the averager through the 200 frequency bins, digitize the voltage output for each bin, normalize and bias the resultant number for display on the CRT and place the number in field L, locations XXXX through XXXX + 200 base 10. XXXX is in decimal. The variable CH must be 0 for the spectrum analyzer and 1 for the spectrum averager. Since CH also designates the analog multiplexer channel number, the analyzer output must be connected to multiplexer channel 0 and the averager output must be connected to channel 1.

As the program is written, the analyzer output will appear in the upper half of the CRT display if the command S A = FSPA(0, 1, 3566) is executed. The averager output will appear in the lower half of the CRT display if one executes the instruction S A = FSPA(1, 1, 3365).

```
FIELD 0

START=3673-242
*BOTTOM
        XSPA-1
*FNTABL+1
        2655
*FNTAB+1
        XSPA
*START
XSPA,   DCA     KOUNT
        TAD     PLIST
        DCA     LSTPTR
GAA,    TAD     LSTPTR
        IAC
        DCA     LSTPTR
        ISZ     KOUNT
        JMS  I  INTEGER
        DCA  I  LSTPTR
        PUSHJ
        ARG
        SKP
        JMP     GAA
        CLL CLA
        CMA                 /AC=-1
        TAD     KOUNT
        SZA                 /IS KOUNT=1 ?
        JMP     T3          /NO, TRY 3
        TAD     LIST        /YES, ERASE OR AVERAGE
        SZA                 /LIST=0 ?
        JMP     T1          /NO, TRY 1
        TAD     AM200       /YES, ERASE AVERAGER
        DCA     ACTR        /SET UP ADDR CTR
        6101                /CLEAR UBIQ FLAG
        6673                /ENABLE EXTERNAL ADDR
        JMS     RUARC       /INIT RAC IN AVE
        6703                /RESET ANALYZER
        6572                /SET AVE SWEEP GATE
LOOP1,  UAER                /ERASE AVERAGE
        6713                /STEP ADDR
        TAD     DLYT        /PICK UP DELAY COUNT
        JMS     DELAY
        ISZ     ACTR
        JMP     LOOP1       /NOT FINISHED
        CLL CLA             /FINISHED
        6574                /RESET AVE SWEEP GATE
        6540                /NOP - DELAY
        JMP  I  EFUN3I      /RETURN TO EXEC
```

```
T1,     TAD     AM1
        SZA             /LIST = 1 ?
        ERROR           /NO, ERROR
        TAD     AM200   /YES, DO AN AVERAGE
        DCA     ACTR    /SET UP ADDR CTR
        6101            /CLEAR UBIQ FLAG
        6673            /ENABLE EXTERNAL ADDR
        JMS     RUARC   /INIT RAC IN AVE
        6703            /RESET ANALYZER
        UAGO            /START AVERAGER
        6572            /SET AVE SWEEP GATE
        6531            /START AVERAGER TRIGGER
LOOP2,  6713            /INCREMENT ADDR
        TAD     DLYT
        JMS     DELAY
        ISZ     ACTR
        JMP     LOOP2
        6574            /RESET AVE SWEEP GATE
        6540            /NOP - DELAY
        JMP I   EFUN31  /RETURN TO EXEC
T3,     TAD     AM1     /SUBTRACT 2 MORE
        TAD     AM1
        SZA             /KOUNT = 3 ?
        ERROR
        TAD     LIST+1  /FIX UP FIELD INSTR
        CLL
        RAL
        RTL
        TAD     FLDINS
        DCA     SETFLD
        TAD     AM200
        DCA     ACTR    /SET UP ADDR CTR
        6101            /CLEAR UBIQ FLAG
        6673            /ENABLE EXTERNAL ADDR
        JMS     RUARC   /INIT RAC IN AVE
        6703            /RESET ANALYZER ADDR
        6572            /SET AVE SWEEP GATE
        UAGO            /START AVERAGER
LOOP3,  6713            /STEP ADDRESS WITH CIRC PLS
        TAD     DLYT
        JMS     DELAY
        6773            /SAMPLE
        6102            /CONVERSION COMPLETE ?
        JMP     .-1     /NO
        JMP     A
RUARC,  0               /INIT RUNNING ADDR CTR
        6572            /SET SWEEP GATE
        6713            /CIRC PULSE
        6574            /RESET SWEEP GATE
```

```
        6540                /NOP - DELAY
        JMP  I  RUARC
PLIST,  LIST-1
DECIMAL
AM200,  -200
OCTAL
AM1,    -1
LSTPTR, 0
PAGE
A,      6101                /CLEAR FLAG
        6774                /YES, GET NUMBER
        6540                /NOP - DELAY
        TAD     M2048       /SHIFT ZERO
        SPA
        CLA CLL
        RTR                 /SCALE FOR DISPLAY
        RTR
        AND     MASK
        DCA     SAMPL
        TAD     LIST
        TAD     M1
        SZA                 /SKIP IF CH = 1
        JMP     CH0         /CH = 0
        CLA                 /CH = 1
        TAD     P1
        6511                /SET MPX CH = 1
        CLA CLL
        TAD     SAMPL
        JMP     SETFLD
CH0,    CLA CLL
        TAD     P0
        6511                /SET MPX CH = 0
        CLA CLL
        TAD     SAMPL
        TAD     P128        /BIAS TO UPPER DISPLAY
SETFLD, 0                   /SET DATA FIELD
        DCA  I  LIST+2
        CDF     0           /SET DATA FIELD TO 0
        TAD     LIST+2      /INCR ADDR
        IAC
        DCA     LIST+2
        ISZ     ACTR
        JMP  I  PLOOP3      /GET NEXT NUMBER
        6574                /RESET AVE SWEEP GATE
        6540                /NOP - DELAY
        JMP  I  EFUN3I      /RETURN TO EXEC
DELAY,  0
        DCA     CTR2
        ISZ     CTR2
```

```
          JMP      .-1
          JMP   I  DELAY
LIST,     Ø
          Ø
          Ø
KOUNT,    Ø
CTR2,     Ø
ACTR,     Ø
SAMPL,    Ø
DLYT,     7700
MASK,     377
FLDINS,   CDF
PLOOP3,   LOOP3
M1,       -1
P1,       1
P0,       Ø
DECIMAL
M2048,    -2048
P128,     128
M200,     -200
OCTAL
UAER=6571
UARE=6532
UAST=6531
UAGO=6534
PUSHJ=4540
EFUN3I=136
ERROR=4566
BOTTOM=35
FNTABL=2165
FNTAB=374
ARG=1553
INTEGER=53
$
```

K. Ross Recorder Driver

The hardware interface for the Ross Laboratories hard copy display unit operates via the data break facility of the PDP-8/L computer. The interface contains logic to unpack each 12-bit word into four 3-bit bytes for display. The data break logic picks up data for unpacking in the order of increasing core address but the stylus travels from right-to-left across the paper. The bytes are unpacked in a left-to-right direction. Therefore, if the normal left-to-right sequence of data is to be output on paper, the 12-bit words must be packed in normal left-to-right order but the words must be stored in the computer core in reverse order.

After scaling the data to be displayed to a value between 0 and 7, the data can be converted to a fixed point integer format, packed four numbers to a computer word and stored in field L, location XXXX by the EXEC instruction S A = FRR(W1, W2, W3, W4, L, XXXX). All variables are in decimal. The variables W1 through W4 are packed in the order shown and stored in location XXXX, field L. In normal applications, 128 (base 10) 12-bit locations have been reserved between 6243 (base 8) and 6444 (base 8) in field 1. The decimal equivalents of these numbers for use in the EXEC level call are 3235 (base 10) and 3364 (base 10) respectively. Storage normally begins at 3364 (base 10) and progresses toward 3235 (base 10).

A second call to XRR, S A = FRR(L, XXXX, N) will set the data break counter at 0 1530 to -N and output N words of core beginning at field L, location XXXX to the hard copy display unit. All arguments are in decimal. The character A is a dummy variable.

```
 /ROSS RECORDER DRIVER PROGRAM

/CALL: S Y=FRR(X1,X2,X3,X4,A,L); PACK X1 THRU X4 INTO L
/CALL: S Y=FRR(A,L,N); SET DATA BREAK COUNTER TO -N, AND
/DISPLAY A LINE FROM FIELD A, FIRST LOCATION L (DECIMAL).

/DATA BREAK COUNTER = 0 1530
/DATA BREAK ADDRESS= =0 1531
FIELD 0
*4                  /PROTECT ROSS RECORDER DATA AREA
6243                /512 BASE 10 LOCATIONS HAVE BEEN RESERVED
FIELD 1             /FOR THE ROSS RECORDER DATA AREA
*3511               /6243B8(3235B10) TO 6444B8(3364B10)
6243

FIELD 0
START=4232-152
*BOTTOM
        KOUNT-1
*FNTAB+16
        XRR
*FNTABL+16
        1166
*START
KOUNT,  0
XRR,    TAD     PLIST   /LIST ADDRESS TO ACTR
        DCA     ACTR
        DCA     KOUNT
        ISZ     KOUNT
        JMS  I  INTEGER /GET NEXT ARG
        DCA  I  ACTR    /STORE IN LIST
        TAD     ACTR
        IAC
        DCA     ACTR
        PUSHJ
        ARG             /GET NEXT CHARACTER
        SKP             /RETURN IF NOT A COMMA
        JMP     XRR+3   /RETURN IF A COMMA, ARG IN FLAC
        CLL CLA
        TAD     KOUNT   /BRANCH ON NUMBER OF ARGS
        TAD     M3
        SZA
        JMP     TEST    /TEST FOR 6 ARGS
DISPLAY,TAD     LIST    /MODIFY INSTRUCTION FOR APPROPRIATE
        SNA             /DATA FIELD
        JMP     DISPRR  /FIELD 0
        TAD     M1
        SZA CLA         /FIELD 1 ?
        ERROR           /NOT FIELD 0 OR FIELD 1
        TAD     RRW
        TAD     MODINS  /ADD MODIFIER
        DCA     RRWRT   /CHANGE WRITE INSTR TO FIELD 1
```

```
DISPRR, TAD     LIST+1  /GET FIRST DATA LOCATION
        TAD     M1      /SUBTRACT ONE
        DCA     RRBA    /INITALIZE BREAK ADDRESS
        TAD     LIST+2  /GET N
        CMA             /COMPLEMENT N
        DCA     RRBC    /INITALIZE BREAK COUNTER
RRWRT,  6153            /SKIP NEXT INSTR AND OUTPUT LINE IF
        ERROR           /RECORDER IS ON, IF NOT THEN
        CLL CLA         /TAKE ERROR EXIT
        TAD     ACTR
        IAC
        DCA     ACTR
        JMP  I  EFUN3I  /RETURN
MODINS, 2
RRW,    6153
PLIST,  LIST
LIST,   0
        0
        0
        0
        0
        0
ACTR,   0
M1,     -1
M3,     -3
CFINS,  CDF     0
TEST,   TAD     M3
        SZA CLA
        ERROR           /WRONG NO ARGS
PACK,   TAD     LIST+4  /SET DATA FIELD INSTR
        RTL
        RAL
        TAD     CFINS
        DCA     CDFL
        TAD     LIST+5  /TRANSFER LOCATION TO STORAGE ON
        DCA     LPTR    /NEXT PAGE
        TAD     LIST    /PACK
        AND     MASK1   /0007
        RTL
        RAL
        DCA     TEM
        TAD     LIST+1
        AND     MASK1
        JMP     N
PAGE
N,      TAD     TEM
        RTL
        RAL
        DCA     TEM
        TAD  I  PLP2
        AND     MASK1
        TAD     TEM
        RTL
        RAL
60,     DCA     TEM
```

```
        TAD  I  PLP3
        AND     MASK1
        TAD     TEM
CDFL,   Ø               /SET DATA FIELD
        DCA  I  LPTR
        CDF     Ø       /SET DF=Ø
        CLA CLL
        JMP  I  EFUN3I  /RETURN
MASK1,  ØØØ7
TEM,    Ø
PLP2,   LIST+2
PLP3,   LIST+3
LPTR,   Ø
INTEGER=53
ARG=1553
PUSHJ=4540
ERROR=4566
EFUN3I=136
RRBA=1531
RRBC=153Ø
BOTTOM=35
FNTAB=374
FNTABL=2165
$
```

L. The Display Driver

The routine XDYS is a multi-purpose driver which is used to service the three D/A converters in the data acquisition system. The output of the D/A converters may be switched to any of three places by a switch on the interface cabinet front panel. Thus, the call FDIS is used to service the CRT display, the three D/A converter outputs on the interface cabinet front panel or the X - Y plotter.

Consider the case in which the front panel switch is set for the D/A converter mode. If X, Y and Z are FOCAL variables with decimal values between 0 and 255, the call S A = FDIS(X, Y, Z) will produce a voltage proportional to the number assigned to X, Y and Z at the BNC connectors labelled X, Y and Z in the D/A section of the interface cabinet front panel. In this mode, the range of available voltages at the BNC connectors is ±10 volts. Numbers in the range 0 to 127 result in positive voltages increasing from 0. Numbers from 128 to 255 result in negative voltages increasing in magnitude from 0 to -10 volts.

When the mode select switch is in the X - Y plotter position, the X and Y converters are switched to the X and Y inputs of the X - Y recorder. The maximum voltage range remains ±10 volts on the X and Y outputs. The Z-axis output is switched to a 0 to +10 volt range and is used to operate a transistor and relay circuit to control the pen up/pen down function. The pen will be placed in the up position and positioned to (X, Y) if the instruction S A = FDIS (X, Y, 0) is executed. If Z is equal to 255, then the instruction is executed, the pen will be put down and moved to the point (X, Y) simultaneously.

Although the CRT display operates through the same software routine, the manner of operation and the software call is slightly different than that indicated above. It is frequently desirable to compute while displaying a picture or function on the CRT display. In order to allow this flexibility, the CRT is updated by the software in EXEC once each time a call is made to the FOCAL

routine EVAL or to the loop which FOCAL uses to idle while awaiting input from some external device.

Provision has been made to store two functions of the same parameter, X, in core memory. The storage area for the first function, Y1, is from 1 6756 (base 8) to 1 7266 (base 8). A function Y2 may be stored in locations 1 6445 (base 8) to 1 6755 (base 8). The function X controls the abscissa for both Y arrays and is stored in locations 1 7267 (base 8) through 1 7577 (base 8). The routine FRAW is often used to load these display storage areas. The function FRAW requires decimal arguments. Therefore, in decimal, the storage area for X ranges from 1 3767 (base 10) to 1 3967 (base 10). The storage area for Y1 ranges from 1 3566 (base 10) to 1 3766 (base 10). The storage for Y2 begins at 1 3365 (base 10) and ends at 1 3565 (base 10).

The numbers entered in these storage locations will be treated as 8-bit positive integers. Therefore they should range between 0 and 255 (base 10). The number (0, 0) represents the extreme left-hand, bottom point in the CRT display area. The center of the display is denoted by (127, 127).

The intensity (Z-axis), wired to range from off (Z = 0) to the brightest value (Z = 255) is controlled by one parameter in each use of the function FDIS. The parameter Z has a special function if its value is zero. In this case, the software considers the display off and does not take time out from the computation to refresh the display. Two software flags are also used to indicate a desire on the part of the EXEC level user to refresh either the function Y1, the function Y2, neither function or both functions at each opportunity. If these flags are designated Y1 and Y2, and the variable Z is between 1 and 255, the EXEC instruction S A = FDIS(1, 1, Z, Y1, Y2) will begin displaying Y1 as a function of the data in the X array, if Y1 = 1; the data in the Y2 array, if Y2 = 1 and the data in both arrays if Y1 = Y2 = 1. The intensity will be set by the value of the argument Z. If Y1 or Y2 is equal to zero, that array will not be refreshed and an increase in the

speed of execution of the program in progress will result. The data from the designated array (s) will be refreshed at each call to EVAL and during idle time until either Z is set to zero or until both Y1 and Y2 are set to zero.

The X array can be set to a ramp function (standard use in the display of time functions or spectra) by executing the EXEC command below.

```
F I = 1, 200; S A = FDIS(1, 3767 - 1+I, 256 * (I - 1)/200).
```

```
FIELD 0
*134
7553            /CHANGE PDL LOCN TO MAKE ROOM FOR
                /DISPLY (ENTRY FROM TDL)
*7536
DISPLY, 0
        CLA CMA
        DCA  I  FLAGP
        TAD     RETAD
        DCA  I  LISTP
        JMP  I  TZM2P
RETTDL, CIF     10
        CDF     10
        JMP  I  DISPLY
FLAGP,  FLAG
LISTP,  LIST
RETAD,  RETTDL
TZM2P,  TESTZ-2
*1613
        JMP  I  PENTRE
PENTRE, ENTRE
*2667
        JMP  I  2670
        ENTRI
BOTTOM=35
*BOTTOM
7777
FNTAB=0374
*FNTAB+3
XDYS
START=4333
*START
KOUNT,  0
ENTRE,  DCA     TLSTOP  /SAVE AC
        DCA     FLAG    /SET FLAG FOR EXIT
        JMP     TESTZ
ENTRI,  IAC
        DCA     FLAG
        RDF             /SAVE CURRENT FIELD
        DCA     MEMTEM
TESTZ,  TAD     LIST+2  /IS Z=0 ?
        SNA CLA         /SKIP ON NON ZERO Z
        JMP     EXIT2   /ZERO Z , EXIT
DECIMAL
        TAD     (-200   /SET CTR
OCTAL
        DCA     CTR
        TAD     X
        DCA     XTEM
        TAD     Y1
        DCA     Y1TEM
        TAD     Y2
        DCA     Y2TEM
        TAD     DATA1   /CHECK FOR DATA1 PRESENT
        JMP     AA
PAGE
```

```
AA,     SNA CLA          /SKIP IF NO DATA PRESENT
        JMP     Y2DIS    /NOT PRESENT
LOOP1,  CDF     10
        TAD  I  Y1TEM    /PICK UP Y1
        CDF     00
        DISY             /SET Y1
        CLA
        TAD     Y1TEM    /INCR Y1 ADDRESS
        TAD     (+1
        DCA     Y1TEM
        CDF     10
        TAD  I  XTEM
        CDF     00
        DISX
        CLA
        TAD     LIST+2
        DISZ
        CLA
        TAD     XTEM
        TAD     (+1
        DCA     XTEM
        ISZ     CTR      /SKIP IF THROUGH
        JMP     LOOP1    /DISPLAY ANOTHER POINT
        DISZ             /TURN INTENSITY OFF FOR RETRACE
Y2DIS,  TAD      DATA2   /IS THERE A Y2 ?
        SNA CLA          /SKIP IF PRESENT
        JMP     EXIT2    /EXIT IF NO MORE
        TAD     X        /RESTORE X ADDR
        DCA     XTEM
        TAD     Y2       /INITALIZE Y2 ADDR
        DCA     Y2TEM
DECIMAL
        TAD     (-200
OCTAL
        DCA     CTR
LOOP2,  CDF     10
        TAD  I  Y2TEM    /PICK UP Y2
        CDF     00
        DISY             /SET Y2
        CLA
        TAD     Y2TEM    /INCR Y2 ADDR
        TAD     (+1
        DCA     Y2TEM
        CDF     10
        TAD  I  XTEM     /PICK UP X
        CDF     00
        DISX             /SET X
        CLA
        TAD     LIST+2   /PICKUP Z
        DISZ             /SET INTENSITY
```

```
        CLA
        TAD     XTEM    /INCR X ADDR
        TAD     (+1
        DCA     XTEM
        ISZ     CTR     /SKIP IF FINISHED
        JMP     LOOP2
        DISZ            /INTENSITY OFF FOR RETRACE
        JMP     EXIT2
XDYS,   TAD     LPT     /ADDRESS OF ARG LIST TO CTR
        DCA     LADR
        DCA     KOUNT
        DCA     DATA1
        DCA     DATA2
FETCH,  ISZ     KOUNT
        JMS I   INTEGER /FETCH NEXT ARG
        DCA  I  LADR
        TAD     LADR
        IAC
        DCA     LADR
        PUSHJ
        ARG             /GET NEXT CHAR
        SKP             /RETURN IF NOT COMMA
        JMP     FETCH   /RETURN IF COMMA
        CLL CLA
        TAD     KOUNT
        TAD     (-3
        SZA             /SKIP ON 3 ARGS; IS X-Y PLOTTER
        JMP     CRT     /IS CRT
        TAD     LIST    /X-Y PLOTTER
        DISX            /SET X
        CLA
        TAD     LIST+1
        DISY            /SET Y
        CLA
        TAD     LIST+2
        DISZ            /SET Z
EXIT1,  CLL CLA
        JMP I   EFUN3I
LPT,    LIST
LIST,   0               /X
        0               /Y
        0               /Z
DATA1,  0
DATA2,  0
LADR,   0
CTR,    0
INBUF=34
XTEM,   0
```

```
Y1TEM,   0
Y2TEM,   0
MEMTEM,  0
INTEGER=53
PUSHJ=4540
ARG=1553
DISX=6501
DISY=6502
DISZ=6504
EFUN3I=136
ERROR2=4566
CRT,     TAD      (-2       /CHECK FOR > 5 ARGS
         SPA SNA
         JMP      EXIT1     /5 ARGS
         ERROR2             /> 5 ARGS
Y1,      6756
Y2,      6445
X,       7267
EXIT2,   TAD      MEMTEM    /RESTORE DATA FIELD
         TAD      MEMINS
         DCA      CHF
CHF,     0                  /62X2 WILL BE STORED HERE
         TAD      FLAG      /TEST FLAG FOR PROPER RETURN
         SNA                /SKIP ON NON ZERO
         JMP      EVL       /ZERO, RETURN TO EVAL VIA EVL
         SPA SNA  CLA       /SKIP IF >0
         JMP  I   LIST      /RETURN TO TIMING LOOP
         TAD      INBUF     /NON ZERO, RETURN TO IDLE LOOP
         SPA SNA
         JMP  I   IRET      /RETURN FOR NO NEW INPUT
         JMP  I   IRETX     /INPUT TO DEAL WITH
IRET,    2671
IRETX,   2672
FLAG,    0
MEMINS,  6202
PAGE
EVL,     TAD      TLSTOP    /PICK UP AC AND
         DCA      LASTOP    /GET READY TO RETURN
         TESTC
         JMP  I   ERET1
         JMP  I   ERET2
         JMP  I   ERET3
         JMP  I   ERET4
```

```
ERET1,    1615
ERET2,   1616
ERET3,   1617
ERET4,   1620
TLSTOP,  0
         LASTOP=55
         TESTC=4564
$
```

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[9] loc. cit., p. 12.

[10] Instruction Manual for the Model 580-10 Research Sonar, SIMRAD, Oslo-Norway.

[11] Listings of FOCAL-69 and MODV are located at data acquisition system site.

[12] "Advanced FOCAL Technical Specifications," Digital Equipment Corporation, DEC-08-AJBB-DL is a useful document if further modifications to EXEC are contemplated.

[13] Programming Languages, PDP-8 Handbook Series, Volume 1, Digital Equipment Corporation, 1970.

[14] Introduction to Programming, PDP-8 Handbook Series, Volume 2, Digital Equipment Corporation, 1970.

APPENDIX I

This appendix contains complete core dump. EXEC was loaded, the initial dialogue was answered YES and the second dialogue was answered N. The core dump routine was then loaded beginning at location 7400 base 8. This locations and successive locations are in the display storage area and therefore the core dump routine does not overlay any part of EXEC. After loading the core dump routine, the following listing of core contents was obtained.

The results of the initial and secondary dialogues with EXEC precede the core dump.

```
CONGRATULATIONS!!
YOU HAVE SUCCESSFULLY LOADED 'EXEC-72-01' ON A PDP-8/L COMPUTER.

SHALL I RETAIN LOG, EXP, ATN ?:YES

PROCEED.

*

YOU ARE NOW USING 8K EXEC-72-01 MOD 0

 DO YOU WANT TO SOFTWARE PROTECT THE LAST PAGE
OF FIELD 1 (7600-7777)(ANS. Y OR N)? N


PROCEED.
?00.00
*
```

```
CORE DUMP - EXEC 72-01 MOD 1  -  FIELD 0
0000    4554 5403 5403 2603 6243 7765 0100 6400
0010    0000 0000 0000 0000 0000 0000 0000 0000
0020    0000 0000 0000 0000 0000 0000 0000 0000
0030    0000 0000 0000 0000 0000 0000 0000 0000
0040    0000 0000 0000 0000 0000 0000 0000 0000
0050    0000 0000 0000 0000 0000 0000 0000 0000
0060    0000 0000 0000 0000 0000 0000 0000 0000
0070    0000 0000 0000 0000 0000 0000 0000 0000
0100    0000 0000 0000 0000 0000 0000 0000 0000
0110    0000 0000 0000 0000 0000 0000 0000 7775
0120    7773 7767 0077 0200 4000 2030 2155 5715
0130    6000 6200 0010 0100 7553 0436 2017 2407
0140    0521 1565 0477 0534 0554 2274 2502 1314
0150    0721 2465 2155 2425 0302 2242 2360 0413
0160    1517 1533 2035 0744 0700 2062 2726 2564
0170    6160 6165 7560 7565 2572 6311 2741 7610
0200    5576 7000 3022 7001 3100 3026 1226 3013
0210    1225 4551 1132 3010 3062 1132 3027 4552
0220    4547 0073 0474 4546 5217 0252 0100 4546
0230    4546 1132 3017 3020 4545 1035 3013 4560
0240    4561 5362 5271 2026 4554 1124 1065 7640
0250    4566 1060 3010 3062 1067 4573 4560 7410
0260    4545 4546 1066 1116 7640 5260 4565 4556
0270    5177 4540 0611 4567 7450 5177 3022 1022
0300    7001 5232 0604 4560 1066 1112 7650 5322
0310    3036 4771 1047 0372 1046 7640 4566 1047
0320    4557 7004 3067 4561 4545 4561 5340 5352
0330    1054 7106 1054 7004 1067 3067 4545 4561
0340    4566 5352 1054 1067 3067 4545 4561 5340
0350    7410 4566 7100 1067 0104 7640 7020 1067
0360    0106 7460 4566 7640 1373 7020 7004 3065
0370    5702 5600 7740 2000 2014 3427 1160 4470
0400    1343 4315 5000 4620 5040 5205 5200 7400
0410    4230 7500 4061 2430 7106 7006 7006 5613
0420    4554 1022 4542 4543 0017 4543 0065 1065
0430    7710 5263 4555 7000 1023 3011 4572 4563
0440    4566 4540 0606 4544 0065 4567 7450 5271
0450    7001 3030 1065 7740 5260 4571 4563 5271
0460    4571 3067 5225 4555 4566 4540 0610 4544
0470    0065 4544 0017 1413 3022 5676 0611 0623
0500    3071 7040 4310 1071 3413 7040 4310 5677
0510    0533 1013 3013 1013 7141 1134 7630 4566
0520    5710 4574 1721 3071 7040 4310 1321 7001
0530    3413 7040 4310 5471 1734 7240 1734 3011
0540    2334 1117 4310 1117 3071 4746 3271 0534
0550    7000 1117 4310 5734 0473 7240 1754 2354
0560    3011 1117 3071 1413 3411 2071 5363 5754
0570    2740 0212 0217 0227 1075 1137 2725 1065
0600    0610 0614 7472 4554 4555 4566 1023 3022
```

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0610    4545 1066 1116 7650 5541 4850 1376 5210
0620    1066 0075 4542 4545 4550 1376 7410 5223
0630    1413 4547 0773 0167 4566 4550 2026 4555
0640    5267 1067 7640 4553 4545 4551 1066 1116
0650    7640 5244 4570 7450 5271 7001 3030 1065
0660    7700 4571 4563 5273 4571 3067 5237 1023
0670    5253 3026 5541 1065 7750 5271 4551 5264
0700    1623 4560 4550 1767 5700 1066 2300 1202
0710    7650 5317 4561 5700 7410 5700 2300 2300
0720    5700 0626 1721 3012 1412 7510 5340 7041
0730    1066 7640 5324 1721 7040 1012 3054 7410
0740    2321 2321 7300 5721 0457 0104 7041 3071
0750    1067 0104 1071 7650 2344 5744 5646 1036
0760    7640 5364 4545 5756 4552 4547 6776 3402
0770    5756 1035 0610 0614 0323 0306 0311 0304
1000    0307 0303 0301 0324 0314 0305 0327 0315
1010    0321 0322 0212 4564 4637 2013 4640 1111
1020    3032 1045 7510 2032 7750 2032 7410 5767
1030    4547 1377 7371 4545 5230 4545 5225 1601
1040    2047 4540 1403 4560 1066 1335 7440 4566
1050    1030 4542 4540 1612 1413 3030 4407 6430
1060    0000 4547 1377 7177 4566 1030 4542 4540
1070    1612 4547 1377 7174 4566 4543 2030 4540
1100    1612 4543 2030 4543 0017 4540 0610 4544
1110    0017 4544 2030 4544 7470 1413 3030 4407
1120    0430 1733 6430 2525 0000 1045 7740 5541
1130    1030 4542 4543 7470 5301 7503 7524 4543
1140    2405 5301 0000 6201 4540 1553 5354 7305
1150    1342 3342 6212 5742 6212 5742 6057 7410
1160    4453 7200 5536 1041 1041 1013 0420 0603
1170    0614 1202 1203 7503 2204 0635 1256 0177
1200    1563 6361 7240 3056 3026 4547 1371 0176
1210    2056 5226 4540 1403 1066 4542 1255 4551
1220    2036 7001 4531 1413 3066 5202 4540 1613
1230    4530 5203 2026 4545 4547 1403 0773 4551
1240    5233 4545 4554 1067 3052 5204 1077 4463
1250    7040 1077 4551 4545 5204 0272 4554 4555
1260    4566 1060 3010 3062 1067 4573 1010 3027
1270    4464 3100 2026 4545 4551 4547 0076 1271
1300    4546 5273 1060 7001 3010 3062 4552 4547
1310    0071 1271 4546 5306 0633 7450 1066 7041
1320    3071 1714 2314 3012 1412 7510 5340 1071
1330    7640 5324 1012 1714 3071 1471 3071 5471
1340    2314 7300 5714 3352 4453 3347 1352 0000
1350    7200 5536 0000 5536 0000 6046 6026 6041
1360    5357 7200 5754 1273 1270 2740 1302 1271
1370    0261 1312 0245 0242 0241 0243 0244 0240
```

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1400    0254 0273 0215 4564 0242 0215 4566 3062
1410    4546 4545 4550 1767 5226 1066 0122 1061
1420    3061 4545 4550 1767 5226 5221 4562 5237
1430    1061 3056 4660 1413 3061 4657 4453 3317
1440    1031 3030 1030 7041 1004 7650 5261 4571
1450    7041 1061 7650 5305 1030 1070 5241 2047
1460    1601 5662 3345 1031 1120 3031 1031 3030
1470    7000 7000 1061 4575 2030 1317 4575 2030
1500    4407 0537 6430 0000 5541 1030 3011 4572
1510    7041 1317 7640 5254 2030 2030 5541 0000
1520    1066 1114 7640 5717 4545 5320 7520 7507
1530    0000 2000 7524 5636 1066 1115 7640 2333
1540    1066 1326 3054 1054 7710 5733 1066 1327
1550    7750 2333 5733 1066 1332 7640 5362 4540
1560    1612 7001 5541 7000 3022 1413 3071 5471
1570    1241 1232 1251 1246 3052 1253 1253 0610
1600    0614 1015 1054 4542 1055 4542 1056 4542
1610    1201 4542 4545 5614 4334 5227 5332 5343
1620    4540 1407 4564 5244 0212 0377 4566 1137
1630    3030 1111 1054 7450 5247 7001 7650 5323
1640    1054 1121 7710 5363 4562 7410 4566 1054
1650    3024 1024 1121 7700 3024 1024 7041 1055
1660    7710 5310 1055 7112 7012 1331 3274 1055
1670    7640 4544 0044 4407 0430 6525 0000 1125
1700    3030 1024 1055 7650 5541 1413 3055 5255
1710    4562 7410 5365 1055 4542 1030 3320 4543
1720    2407 1024 3055 4545 4564 5363 5332 5343
1730    5220 0430 4543 0044 1125 3030 3036 4531
1740    4544 0044 5222 3056 4545 4550 1767 5354
1750    1056 7104 1066 5343 4562 4566 4201 1413
1760    4547 2164 6207 4562 4566 4201 2013 5536
1770    0240 0253 0255 0257 0252 0336 0250 0333
2000    0274 0251 0335 0276 0254 0273 0215 0275
2010    4543 2405 4544 0044 1231 7710 4451 4407
2020    7000 6230 0000 1125 3030 4247 5627 1622
2030    0000 0000 0000 0000 0003 1645 1054 1121
2040    7700 5635 1054 1120 7740 2235 5635 1017
2050    1413 3055 1234 1413 7041 1054 7640 4566
2060    4545 5647 0000 6002 4555 5662 2026 4545
2070    1066 1116 7640 5267 1017 7040 1023 3057
2100    1133 7041 1023 7650 5177 6211 1423 3425
2110    1133 3071 1471 7450 5327 3032 1023 7141
2120    1032 7630 1057 1032 3471 1032 5311 7040
2130    1023 3011 1057 7040 1023 3012 1057 1060
2140    3060 1010 7040 1012 3032 1010 1057 3010
2150    1412 3411 2032 5350 5263 0220 4464 3066
2160    4550 1623 5755 5764 3330 2533 2655 2636
2170    2565 2622 2517 2572 2624 2625 2654 2575
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2200    2702 2641 2564 1166 4564 5237 5222 5213
2210    1066 1112 7440 4566 1135 3060 6211 3533
2220    6201 5177 4554 1060 3010 4565 2023 1065
2230    7700 4570 4563 5177 4570 3067 5225 1004
2240    3031 5541 0606 1133 3025 1133 3023 1023
2250    3011 1067 7141 4572 7450 5266 7630 5267
2260    1023 3025 4570 7440 5246 7410 2242 1023
2270    7001 3017 3020 5642 0624 4330 7710 1006
2300    1357 1066 7450 5316 1075 3066 1026 1100
2310    7650 4551 5674 4330 7040 5276 1026 7640
2320    5326 1100 7650 7001 3100 5275 1110 5305
2330    2314 2020 5345 1021 0122 3066 1066 1103
2340    7650 5313 1066 1356 5730 4574 3021 7040
2350    3020 1021 7112 7012 7012 5334 7740 7641
2360    0000 6211 1425 3460 1060 3425 1061 7440
2370    3410 1010 7001 3060 6201 5760 5760 1253
2400    0614 6202 0757 0757 6250 0001 2000 0000
2410    0000 0000 0000 7766 0000 6031 5215 6036
2420    0106 7450 5215 1123 5614 2766 1067 4557
2430    0122 4242 1102 4551 1067 4242 1356 3066
2440    4551 5625 2436 0106 3032 1113 3033 5252
2450    2033 3032 1032 1213 7500 5250 7200 1033
2460    4551 1032 1113 4551 5642 0212 7450 1066
2470    1116 7450 5276 1077 4463 5665 1077 4463
2500    1076 5274 1411 1110 7041 1066 7450 1352
2510    1101 7450 5755 1353 3071 1071 0354 1356
2520    7440 1354 7650 5332 1071 0122 7440 4335
2530    6201 5702 1122 4335 5324 2530 2062 5357
2540    1061 4573 3061 1031 1005 7141 1010 7620
2550    5735 4566 0040 0377 0140 3004 7640 4557
2560    3061 7040 3062 5735 2770 6211 1422 6201
2570    5764 7402 0000 6211 1417 6201 5772 7402
2600    0000 0000 7575 3200 7010 3201 6041 5225
2610    6042 3016 1665 7450 5225 6044 3016 3665
2620    1265 7001 0107 1263 3265 6031 5246 6036
2630    0106 7450 5246 1123 3262 1262 1202 7650
2640    5340 1034 7640 4566 1262 3034 6011 5252
2650    6012 3037 5653 3673 1201 7104 1200 6244
2660    6001 5400 0215 3120 3132 3132 2157 5670
2670    4337 5267 3276 3034 1276 5666 2475 3266
2700    6001 1664 7640 5301 6002 1016 7640 5314
2710    1266 6046 3016 5323 1266 3664 1264 7001
2720    0107 1263 3264 6001 5676 3326 0000 7240
2730    1326 3067 6001 1016 7640 5333 6002 5342
2740    1123 3067 2016 1105 3057 7040 1263 3010
2750    6201 3410 2057 5351 3034 1263 3265 1263
2760    3264 7040 6046 1101 4551 4553 2022 4567
2770    7450 5377 3067 1101 4551 4551 4553 1077
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3000    4551 1126 3152 5177 1062 7640 5214 1010
3010    7041 1027 7700 5641 1251 4551 1010 3071
3020    6211 2062 5242 1471 0122 1103 7640 5237
3030    7040 3062 7040 1010 3010 1471 0101 3061
3040    5641 2530 1471 0101 1006 7640 5230 3471
3050    5231 0334 1031 3030 1004 7041 1030 7650
3060    5541 4571 5716 1315 3017 3020 4545 4551
3070    4545 4551 4545 4551 2030 4571 4714 4545
3100    4551 2030 4407 0430 0000 4530 1077 4551
3110    1070 1111 1030 5253 2442 0003 7572 5051
3120    0000 0000 0000 0000 0000 0000 0000 0000
3130    0000 0000 0000 0000 0000 0000 0000 0000
3140    0000 2340 1761 3363 1763 0362 1364 7640
3150    5356 1765 1366 7650 5356 2367 1440 3040
3160    5740 6400 0777 0000 7350 0030 5750 0000
3170    7402 7402 7402 7402 7402 7402 7402 7402
3200    0000 2200 1622 7650 5214 6211 1415 6201
3210    3414 2057 5205 5220 1415 3414 2057 5214
3220    3622 5600 3167 0000 2223 1622 7650 5246
3230    1014 1270 7640 4253 4262 6201 1414 6201
3240    3415 6201 2057 5235 3622 5623 1414 3415
3250    2057 5246 5623 0000 2253 1205 3235 1207
3260    3237 5653 0000 1205 3237 1207 3235 5662
3270    7735 0000 2271 1671 3325 2271 1725 1324
3300    7640 5317 1011 1326 7650 5317 1011 1327
3310    7650 5317 4572 3413 2071 5312 5671 1411
3320    3413 2071 5317 5671 6057 0000 5751 5372
3330    3342 7604 7004 7200 1342 7420 4743 1744
3340    3342 5742 0000 2465 2155 1031 1005 7141
3350    1060 7630 4566 5754 1463 3044 3045 3046
3360    1372 3763 5763 1553 3771 3044 1373 3763
3370    5536 1530 4407 5762 6201 5776 2010 1401
3400    0255 7042 7715 3421 0250 1140 5020 0420
3410    5564 3703 6441 5611 7001 3220 6444 5611
3420    0000 0000 6201 4453 6212 5621 5542 3777
3430    1362 3365 1365 7001 3365 2777 4453 3765
3440    4540 1553 7410 5232 7300 7040 1777 7440
3450    5321 1776 7440 5275 1363 3775 6101 6673
3460    4352 6703 6572 6571 6713 1774 4773 2775
3470    5263 7300 6574 6540 5536 1364 7440 4566
3500    1363 3775 6101 6673 4352 6703 6534 6572
3510    6531 6713 1774 4773 2775 5311 6574 6540
3520    5536 1364 1364 7440 4566 1772 7100 7004
3530    7006 1771 3770 1363 3775 6101 6673 4352
3540    6703 6572 6534 6713 1774 4773 6773 6102
3550    5347 5767 0000 6572 6713 6574 1774 4773
3560    6540 5752 3651 7470 7777 0000 6073 3600
3570    3632 3663 3653 3645 3661 3657 3652 3655
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3600    6101 6774 6540 1270 7510 7300 7012 7012
3610    0262 3260 1252 1265 7440 5224 7200 1266
3620    6511 7300 1260 5232 7300 1267 6511 7300
3630    1260 1271 0000 3654 6201 1254 7001 3254
3640    2257 5664 6574 6540 5536 0000 3256 2256
3650    5247 5645 0000 0000 0000 0000 0000 0000
3660    0000 7700 0377 6201 3543 7777 0001 0000
3670    4000 0200 7470 6021 5276 6022 4301 5700
3700    2654 3677 4705 7000 5701 3411 0000 7240
3710    3777 7200 1016 7440 5312 6002 1360 3063
3720    1361 3064 1362 3746 1363 3747 1364 3750
3730    1363 3755 2777 5341 1365 3751 1366 3752
3740    5756 1367 3753 1370 3754 5757 2732 2762
3750    1357 0671 0672 1577 1600 1355 0635 1203
3760    1354 2414 5336 7000 6021 5672 4006 3771
3770    3772 1776 1775 5774 4000 4047 4034 4036
4000    3235 1246 3655 1247 3656 5215 1247 3235
4010    3026 1244 3653 1245 3654 1237 3063 1240
4020    3064 1241 3650 1242 3651 1243 3652 1242
4030    3657 3236 6001 5635 7774 0000 0000 2676
4040    2666 6001 6046 6041 3026 5541 0610 0614
4050    2732 2762 1357 0671 0672 1577 1600 1355
4060    0000 1333 3342 3260 2260 4453 3742 1342
4070    7001 3342 4540 1553 7410 5264 7300 1260
4100    1344 7440 5346 1334 7450 5314 1343 7640
4110    4566 1332 1331 3322 1335 1343 3777 1336
4120    7040 3776 6153 4566 7300 1342 7001 3342
4130    5536 0002 6153 4134 0000 0000 0000 0000
4140    0000 0000 0000 7777 7775 6201 1344 7640
4150    4566 1340 7006 7004 1345 3775 1341 3774
4160    1334 0773 7006 7004 3772 1335 0773 5771
4170    7402 4200 4223 4222 4226 4215 1530 1531
4200    1223 7006 7004 3223 1624 0222 1223 7006
4210    7004 3223 1625 0222 1223 0000 3626 6201
4220    7300 5536 0007 0000 4136 4137 0000 0000
4230    1305 3304 3227 2227 4453 3704 1304 7001
4240    3304 4540 1553 7410 5233 7300 1306 7006
4250    7004 1313 3261 1261 3271 1227 1311 7440
4260    5265 0000 1707 6201 5275 1314 7640 4566
4270    1310 0000 3707 6201 1310 7110 3045 7010
4300    3046 1312 3044 5536 0000 4306 0000 0000
4310    0000 7776 0014 6201 7777 4453 6511 6773
4320    6102 5320 6774 7110 3045 7010 3046 1332
4330    3044 5536 0014 0000 3777 3776 5343 7001
4340    3776 6214 3775 1774 7650 5773 1372 3771
4350    1770 3767 1766 3765 1764 3763 1762 5761
4360    0443 4400 4532 4540 4547 4537 4546 4536
4370    4550 4535 7470 4551 4531 4541 4570 4613
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4400    7650 5230 6211 1737 6201 6502 7200 1337
4410    1377 3337 6211 1736 6201 6501 7200 1331
4420    6504 7200 1336 1377 3336 2335 5202 6504
4430    1333 7650 5351 1350 3336 1347 3340 1376
4440    3335 6211 1740 6201 6502 7200 1340 1377
4450    3340 6211 1736 6201 6501 7200 1331 6504
4460    7200 1336 1377 3336 2335 5241 6504 5351
4470    1326 3334 3775 3332 3333 2775 4453 3734
4500    1334 7001 3334 4540 1553 7410 5275 7300
4510    1775 1374 7440 5342 1327 6501 7200 1330
4520    6502 7200 1331 6504 7300 5536 4527 0000
4530    0000 0000 0000 0000 0000 0000 0000 0000
4540    0000 0000 1373 7550 5324 4566 6756 6445
4550    7267 1341 1371 3354 6202 1370 7450 5772
4560    7750 5727 1034 7550 5766 5767 2671 2672
4570    0001 6202 4600 7776 7775 4333 7470 0001
4600    1213 3055 4564 5607 5610 5611 5612 1615
4610    1616 1617 1620 0000 6202 0000 7402 7402
4620    1045 7710 4724 3033 4407 4313 6675 0000
4630    4453 3325 4407 7000 6676 0675 2676 6675
4640    4675 6676 1310 6326 0305 3326 2675 1277
4650    6326 0302 4676 1326 6326 0675 3326 4321
4660    1316 0000 1325 1044 3044 2033 5536 4407
4670    6675 0316 3675 0000 5536 5322 5326 0004
4700    2372 1402 7774 2157 5157 0012 5454 0343
4710    0007 2566 5341 0001 2705 2435 0001 2000
4720    0000 0002 2000 0000 5163 0000 0000 0000
4730    0000 0000 4407 0675 4675 6676 4374 1371
4740    4676 1366 6326 0363 4676 1360 4676 1355
4750    4675 3326 0000 5754 5024 0000 2437 1643
4760    7777 3304 4434 7773 3306 5454 0000 2437
4770    1646 0000 2427 2323 7775 3427 7052 7402
5000    1045 7710 4363 3033 4407 6635 2637 0000
5010    1045 7710 5221 4407 0637 3635 6635 0000
5020    7240 3362 5623 4732 2362 5634 4407 6635
5030    0636 2635 0000 5634 5302 5322 5316 4716
5040    1045 7450 4566 7710 4451 4407 6756 2637
5050    0000 1045 7450 5536 7700 5264 4407 0637
5060    3756 6756 0000 7240 3033 5367 3044 7040
5070    1756 3045 3046 3047 7001 3756 4407 4357
5100    6635 0756 2637 6756 4353 1350 4756 1345
5110    4756 1342 4756 1337 4756 1334 4756 1331
5120    4756 1326 4756 1635 0000 5634 0000 3777
5130    7742 7777 4000 4100 7777 2517 0307 7776
5140    4113 7211 7776 2535 3301 7775 4746 0771
5150    7774 2236 4304 7771 4544 1735 4726 0000
5160    2613 4414 0000 0000 4451 7240 5763 1005
5170    7041 5266 7402 7402 7402 7402 7402 7402
5200    4407 6322 0316 2322 0000 1045 7740 5215
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5210    1045 7700 5536 4451 7040 3033 4407 3306
5220    6326 0000 4453 4407 7000 6322 0326 2322
5230    4306 6322 2312 0000 1045 7710 5245 4407
5240    6322 0000 1033 7040 3033 4407 0322 2316
5250    0000 1045 7710 5261 4407 0312 2322 6322
5260    0000 4407 0322 3316 6322 4322 6326 0332
5270    4326 1336 4326 1342 4326 1346 4326 1316
5300    4322 0000 2033 5536 4451 5536 0003 3110
5310    3756 3235 0002 3110 3756 3235 0001 3110
5320    3756 3235 0000 0000 0000 0000 0000 0000
5330    0000 0000 7764 2501 7015 1042 7771 5464
5340    5514 6150 7775 2431 5361 4736 0000 5325
5350    0414 3167 7402 7402 7402 7402 7402 7402
5360    7402 7402 7402 7402 7402 7402 7402 7402
5370    7402 7402 7402 7402 7402 7402 7402 7402
5400    0000 3334 1052 4557 0122 3032 1032 7041
5410    7450 1326 3335 1052 7450 5241 0122 3333
5420    1335 1333 7510 5230 7240 1032 3333 7040
5430    1033 7500 7200 1032 7510 5263 1326 7500
5440    7200 1327 3071 1731 1071 3336 1071 7041
5450    3071 1325 2736 1736 1330 7710 5265 3736
5460    2071 5321 2736 2033 7200 1052 7650 5356
5470    1335 1033 7540 5355 1333 7500 7200 7041
5500    1033 7041 3032 1033 1032 7650 5343 1032
5510    7001 7710 1105 4336 2032 5303 1102 4551
5520    5303 7040 1336 3336 5252 0005 7772 0007
5530    7766 6150 6154 0000 0000 0000 0000 4732
5540    2335 5736 5600 7040 1033 3033 2334 5353
5550    7040 3334 5313 1414 5313 7200 4732 1102
5560    4551 2200 1414 4336 2334 5362 7040 3334
5570    5363 7337 1045 3050 1045 7710 4451 5771
5600    6210 3046 3044 3045 3047 3314 3050 1066
5610    1264 7450 5220 1111 7640 5221 7040 3050
5620    4666 1066 1265 7650 5220 4227 5600 5626
5630    1066 1262 7650 5627 4561 5627 5247 1054
5640    3313 4267 2314 7640 4566 4666 5230 1066
5650    1112 7710 5627 1066 1263 7740 5627 1066
5660    0122 5240 7473 7446 7525 7540 0756 5642
5670    1047 3043 1046 3042 1045 3041 3312 4315
5700    4315 4333 4315 1313 3043 3042 3041 4333
5710    1312 5667 0000 0000 0001 5703 1047 7104
5720    3047 1046 7004 3046 1045 7004 3045 1312
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5740    7004 1046 1042 3046 7004 1045 1041 3045
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7470    0002 2000 0000 0000 0000 0000 0000 7503
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7570    6201 5765 6211 3776 6201 5777 0004 3063
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7770    7402 7402 7402 7402 7402 7402 7402 7402
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CORE DUMP - EXEC 72-01 MOD 1  -  FIELD 1
0000    0000 0000 0000 0000 0000 5051 0060 0436
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0020    7402 7402 7402 7402 7402 7402 7402 7402
0030    7402 7402 7402 7402 7402 7402 7402 7402
0040    7402 7402 7402 7402 7402 7402 7402 7402
0050    7402 7402 7402 7402 7402 7402 7402 7402
0060    7402 7402 7402 7402 7402 7402 7402 7402
0070    7402 7402 7402 7402 7402 7402 7402 7402
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0110    5560 6140 7715 2726 2017 3421 1142 0363
0120    0000 0000 0000 6203 5525 7600 7402 7402
0130    0143 6041 5131 6046 7200 5530 3277 1144
0140    4130 1145 4130 5536 0215 0212 7701 0077
0150    7402 7402 7402 7402 7402 7402 7402 7402
0160    7402 7402 7402 7402 7402 7402 7402 7402
0170    7402 7402 7402 7402 7402 7402 7402 7402
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0210    5234 1731 1333 7640 5232 1730 1332 7640
0220    5232 6202 4516 6202 4513 6211 6202 4515
0230    6202 5720 5633 0400 6202 4516 6202 4513
0240    6202 4515 3121 1723 3120 1724 1325 7440
0250    5260 1121 7104 3121 7004 1120 7104 3120
0260    7750 5265 6202 6201 4513 1322 3327 3326
0270    2326 6202 4516 7000 5305 6202 4515 6211
0300    3727 1327 7001 3327 5270 1317 1326 7640
0310    5223 6211 2716 5336 5715 0416 0435 7776
0320    3374 0046 0122 0045 0044 7750 0000 0000
0330    2030 2031 7765 4100 7764 5776 7300 1121
0340    7040 3121 7004 1120 7040 3120 4363 2121
0350    5346 2120 5346 1122 3355 0000 7300 3716
0360    6201 6202 5514 0000 1373 3372 2372 5366
0370    7000 5763 0000 7761 7402 7402 7402 7402
0400    1626 1233 7640 5210 1627 1234 7650 5212
0410    6202 4513 6211 7040 3235 5632 6201 6442
0420    1631 7650 5220 3631 6211 5630 2031 2030
0430    0336 3420 0234 5563 7764 0000 7402 7402
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0450    7402 7402 7402 7402 7402 7402 7402 7402
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1010    7402 7402 7402 7402 7402 7402 7402 7402
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1110    7402 7402 7402 7402 7402 7402 7402 7402
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3770    7402 7402 7402 7402 7402 7402 7402 7402
4000    7402 7402 7402 7402 7402 7402 7402 7402
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7360    7402 7402 7402 7402 7402 7402 7402 7402
7370    7402 7402 7402 7402 7402 7402 7402 7402
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7400    7402 7604 0356 3350 1351 1350 3207 6211
7410    7402 7604 3276 7402 7604 7040 1276 3277
7420    7300 4265 4342 7041 1304 7640 5222 5232
7430    2300 5245 1307 3300 4265 1276 4702 1306
7440    3265 1305 4257 2265 5241 7200 1676 4702
7450    1305 4257 2276 2277 5230 4265 5200 7452
7460    6046 6041 5261 7200 5657 0000 7200 1304
7470    4257 1303 4257 1310 4333 5665 7476 7477
7500    7770 0000 7511 0212 0215 0240 7774 7770
7510    7766 7450 3354 1357 3353 1354 7004 7004
7520    7006 3354 1354 0360 1361 4755 1354 2353
7530    5317 7200 5711 7475 3301 1305 4257 2301
7540    5335 5733 7423 6031 5343 6036 6046 5742
7550    0010 6201 0000 0000 0000 7457 0070 7774
7560    0007 0260 7402 7402 7402 7402 7402 7402
7570    7402 7402 7402 7402 7402 7402 7402 7402
7600    0000 6211 0200 4505 7562 7733 3200 4237
7610    1275 7750 5216 2200 7040 5206 1200 7640
7620    5207 1202 0271 1347 7510 2205 7750 5605
7630    1202 0235 1236 3201 5207 0070 6201 7610
7640    5247 6031 5241 6036 3202 1202 5637 6011
7650    5247 6016 5244 1367 6122 6114 6111 5256
7660    6112 3202 1202 0364 7440 7402 1202 0370
7670    5244 0300 4351 7041 1203 7402 6032 6014
7700    6214 1236 3201 7604 0365 7440 5314 7604
7710    0364 3367 1366 5316 7604 7700 1361 1360
7720    3240 4205 5321 3203 1201 3344 1202 3376
7730    4237 3363 4205 5272 4351 7420 5344 3204
7740    1376 1363 1203 5323 6211 3604 2204 7600
7750    5340 7673 1376 7106 7006 7006 1363 5751
7760    5241 0006 0000 0005 6000 0001 0004 0000
7770    0377 7777 0000 0000 7777 7777 0045 5276
0000    0000
```

APPENDIX II

Field 0

0	EXEC
1142	GETARG
1155	FREE
1160	EXEC
3374	XSGNE
3377	FREE
3411	SERVEX
3421	INTF1
3427	XSPA
3673	INT HNDLR
3707	H S P and W
4060	XRR
4227	XRAW
4315	A/D
4333	XDYS
4614	FREE
4620	EXT FNS
7500	XGEN ENTRY
7503	LIB COMM PROC
7536	DISPL ENT/TDL
7553	PUSH DOWN LIST
7777	

Field 1

0	8K OVERLAY
0114	ERROR1 ADDR
0115	EFUN3I ADDR
	FREE
0200	XGEN
0436	USER AREA PROGRAM AND DATA STORAGE
6243	RR ARRAY
6445	Y2-ARRAY
6756	Y1-ARRAY
7267	X-ARRAY
7600	RTBIN LOADER
7777	

APPENDIX III

The routine WTBIN is used to write blocks of binary formatted data to a selected magnetic tape cassette. The routine starts at address 7000 (base 8) in either field of core. The routine punches 100 (base 8) leader/trailer code characters, the designated block of data in binary format with field and/or location codes and then punches a checksum followed by 100 (base 8) more trailer characters (200 base 8).

To use the program, load the WTBIN tape via the binary loader RTBIN or BIN. Set the switch register (SR) to the starting address 7000 (base 8) and press load address. The program will halt. Enter the deck and unit of the magnetic tape cassette on which a write is to be performed in SR bits 0 and 1 respectively. Press the continue switch. The computer will halt again. Enter the number of blocks to be written to tape (all blocks must be in the same field) into the SR. Press continue. When the computer halts, enter the first address in the block to be written to tape into the SR. Press continue again. When the computer stops, enter the final address into the switch register and press continue again. The tape selected should move forward and the write should take place. When the tape and the computer stop, the initial address of the second block, if any, should be entered, continue pressed and the final address of the second block entered. Pressing continue will initiate a second write operation. The process may be continued until all blocks have been written.

The field from which the data is taken in the write operation is set by the position of the data field switch at the time the load address switch is depressed. In multiple block writes, the program must be restarted each time the data field must be changed from its initial value.

If the computer halts at 7043 (base 8), the halt was normal. If the computer stops at 7110 (base 8) an error condition exists. A halt at this location with

accumulator bit 0 equal to 1 indicates a tape error output. If bit 1 of the accumulator is 1, the read control is depressed on the tape deck front panel, the cassette is missing or misaligned or the write interlock is out. If both AC0 and AC1 are one, the end-of-tape flag has been encountered.

```
/**************WTFIN**************


TWSF=6121
TWLS=6126
THRP=6112
        *7000
START,  HLT             /ENTER DECK,UNIT;AC0,1
        LAS
        DCA ADDR        /STORE DECK,UNIT
        HLT             /SET SWITCHES=NO. BLOCKS
        LAS
        CIA
        DCA NP          /STORE MINUS NO. BLOCKS
NXBL,   HLT             /SET SWITCHES = INITIAL ADDRESS
        LAS
        DCA IA
        HLT             /SET SWITCHES = FINAL ADDRESS
        LAS
        IAC
        DCA FA
        DCA CKSM        /CLEAR CHECKSUM
        JMS PLOT        /GO WRITE LEADER CODES
        CLA
        TAD IA
        STL             /TO WRITE IA AS ORIGIN
PUNL,   JMS BINP        /GO WRITE WORD AS TWO LINES
                        /OF TAPE
        TAD IA
        CIA
        TAD FA          /AC=FA-IA
        SNA CLA         /WAS IT LAST WORD OF BLOCK ?
        JMP .+5         /IT WAS LAST WORD
        TAD I IA        /GET WORD TO WRITE
        CLL             /NOT AN ORIGIN
        ISZ IA          /JUST INDEX IA
        JMP PUNL
        TAD CKSM
        CLL
        JMS BINP        /GO WRITE CHECKSUM
        JMS PLOT        /GO WRITE TRAILER CODES
        ISZ NP          /IS THERE ANOTHER BLOCK ?
        JMP NXBL        /HANDLE NEXT BLOCK
        HLT             /DONE
        JMP START
PLOT,   0
        CLA CLL
        TAD M100        /TO PUNCH 100 OCTAL LEADER-
                        /TRAILER CODES
```

```
        DCA CTR1
        TAD C200        /LEADER-TRAILER CODE
        JMS PUN         /WRITE C(AC)
        ISZ CTR1        /ANOTHER L-T CODE OR NOT ?
        JMP .-2          /GO WRITE ANOTHER
        JMP I PLOT      /EXIT
FINP,   0
        DCA TEM1
        TAD TEM1
        RTR
        RTR
        RTR
        AND SL7         /FIRST TWO OCIAL DIGITS IN
                        /AC5-11
        JMS PUN         /WRITE C(AC)
        TAD CKSM
        DCA CKSM
        TAD TEM1
        AND SL6         /LAST TWO OCTAL DIGITS IN
                        /AC6-11
        JMS PUN         /WRITE C(AC)
        TAD CKSM
        DCA CKSM
        JMP I FINP      /EXIT
PUN,    0               /GET TAPE ADDRESS, WRITE C(AC)
        DCA TEM2
        TAD TEM2
        TAD ADDR        /TO TAPE
        TWLS            /WRITE IT
        TWSF            /CHECK FLAG
        JMP .-1         /LOOP TILL NO IS WRITTEN
        TRRB            /CHECK FOR TAPE ERROR
        AND EMASK        /MASK WITH 6000
        SZA
        HLT             /HALT HERE ON TAPE ERROR
                        /AC0=TAPE ERROR OUTPUT
                        /AC1=READ CONTROL DEPRESSED OR
                        /CASSETTE MISSING OR
                        /WRITE INTERLOCK OUT
                        /AC0,1=END OF TAPE ENCOUNTERED
        TAD TEM2
        JMP I PUN       /EXIT WITH C(AC) UNALTERED
CKSM,   0
NE,     0
IA,     0
FA,     0
M100,   -100
CTR1,   0
C200,   200
TEM1,   0
SL7,    177
```

```
SL6.    77
ADDR.   0
EMASK.  6000
TEM2.   0
$
```

APPENDIX IV

To load EXEC-72-01 Mod 1 with RTBIN:

1. Set SR = 7777, Mem. Prot. = 0, Instr. Field = 1.
2. Press the load address switch.
3. Set SR = 3777.
4. Mount EXEC paper tape in the high-speed reader.
5. Press the start switch.
6. Tape reads in (if RTBIN is ok and "load" light on reader is off).
7. Set SR = 0200, Mem. Prot. = 1, Instr. Field = 0, Data Field = 0.
8. Press the load address switch and the start switch.
9. Answer YES to initial dialogue.
10. Press stop switch after printing on TTY stops.
11. Run tape forward past 1X1.
12. Set SR = 7777, Mem. Prot. = 0, Instr. Field = 1, Data Field = 0, press load address switch.
13. Set SR = 3777.
14. Press start switch.
15. Wait until remaining tape is read and reader stops.
16. Set location 0 1217 = 7600 if you wish to suppress the : on execution of the ASK command.
17. If you require the Ross recorder, set 0 0004 equal to 6242 and 1 3511 to 6242.
18. If you do not require the Ross recorder data area, you can gain 200 (base 8) words of storage by setting 0 0004 to 6444 and 1 3511 to 6444.
19. If you do not require both CRT display areas, the area Y2 can be used for added program and data storage by setting 0 0004 equal to 6755 and 1 3511 to 6755.
20. If no CRT display is desired, additional space can be obtained for program and data storage by setting both 1 0004 and 1 3511 to 7776.

21. After choosing between the options in steps 17 through 20 above, set the memory protect switch to 1, the instruction field to 0 and the data field to 0. Set the switch register (SR) to 0200 and
22. Press the load address switch.
23. Press the start switch, answer N to the second dialogue and proceed to load and run the EXEC level program.

APPENDIX V

The service routine RTBIN is used to load data in a binary, block format from the low-speed paper tape reader, the high-speed paper tape reader and the magnetic tape cassettes. This routine is designed to reside in the last (7600 - 7777) page of field 1. Both BIN format and RIM format tapes are available for loading by the binary loader (BIN) or the RIM loader supplied by DEC.

To use RTBIN to read from the magnetic tape cassettes once it resides in core, set SR = 7777 and press load address. Next, set bit 11 of the SR to zero and bits 0 and 1 of the SR equal to the deck and unit number of the magnetic tape cassette to be read. Press the start switch to initiate the read process. If at the end of the read sequence, the tape and computer will both stop. An error has occurred if the accumulator is non-zero. The accumulator contents can indicate either a checksum error or, if only bits 0 and/or 1 are non-zero, a tape error output (bit 0 = 1) or if bit 1 is one, the read control is depressed, the cassette is missing or misaligned, or the write interlock is out. If both AC0 and AC1, the end-of-tape flag has been set. The latter error conditions are discussed further in the hardware section of this document.

The high-speed and low-speed paper tape readers are used in the same manner as the DEC binary loader BIN. The starting address is 7777. The switch register (SR) bit 11 is left at one to select the high or low-speed reader and the position of the (SR) bit 0 indicates the low-speed reader if set to one and the high-speed reader if set to zero. Pressing start initiates the read.

RTBIN is normally protected by placing the memory protect switch up. This procedure is advised at any time RTBIN is not in use.

```
                        /BINARY LOADERS FOR ASR 33
                        /READER, HI SPEED READER AND
                        /THE MAGNETIC TAPE CASSETTE DECKS
                        /USE RIM LOADER IN LOW CORE (FIELD 1);
                        /MEMORY PROTECT SWITCH OFF
                        /TO LOAD BINT INTO
                        /HI CORE (FIELD 0)

TRSF=6111
TRRB=6112
TRFC=6114
TWSF=6121
TWCF=6122
TWPC=6124
TWLS=6126
*7600
SWITCH, 0
MEMTEM, 0
CHAR,
CHKSUM, 0
ORIGIN, 0

                        /EXTRACT ERRORS, FIELD, L/T

BEGG,   0
        DCA SWITCH      /SET SWITCH
        JMS READ        /GET A CHARACTER
        TAD M376        /TEST FOR 377
        SPA SNA CLA
        JMP .+4         /NO
        ISZ SWITCH      /YES: COMPLEMENT SWITCH
        CMA
        JMP BEGG+1
        TAD SWITCH      /NOT 377
        SZA CLA         /IS SWITCH SET ?
        JMP BEGG+2      /YES; IGNORE
        TAD CHAR        /NO; TEST FOR CODE
        AND MASK        /TYPES
        TAD M200
        SPA
        ISZ BEGG        /DATA OR ORIGIN
        SPA SNA CLA
        JMP I BEGG      /DATA,ORIGIN OR L/T
        TAD CHAR        /FIELD SETTING
        AND FMASK
        TAD CHANGE
        DCA MEMTEM
        JMP BEGG+2      /CONTINUE INPUT
FMASK,  70
```

```
CHANGE, CDF
READ,   0
        0
LOR,    KSF             /WAIT FOR FLAG
        JMP .-1
        KRB
        DCA CHAR
        TAD CHAR
        JMP I READ
HIR,    RSF
        JMP .-1
        RRB RFC
        JMP LOR+3
TAPE,   TAD ADDR
        TRFC
        TRSF
        JMP .-1
        TRRB
        DCA CHAR
        TAD CHAR
        AND EMASK       /CHECK FOR TAPE ERROR
        SZA
        HLT             /TAPE ERROR
        TAD CHAR        /AC0=TAPE ERROR OUTPUT
        AND CHMSK       /AC1=READ CONTROL DEPRESSED OR
        JMP LOR+1       /CASSETTE MISSING OR
                        /WRITE INTERLOCK OUT
MASK,   300

                        /TRAILER CODE SEEN


BEND,   JMS ASSEMP
        CIA
        TAD CHKSUM
M376,   HLT


BEGIN,  KCC
        RFC
        RDF
        TAD CHANGE
        DCA MEMTEM      /SAVE FIELD INSTRUCTION
        LAS
        AND TMASK       /AC=0 IF BIT 0=0; SKIP TO READ TAPE
        SZA             /IF BIT 0 NOT 0, TRY ASR33 OR
        JMP RDR         /HI SPEED READER
        LAS
        AND EMASK       /ADDRESS MASK
        DCA ADDR
        TAD TPRI
        JMP RDR+2
```

```
RDR,    LAS
        SMA CLA
        TAD HIRI
        TAD LORI
        DCA READ+1
        JMS BEGG
        JMP .-1          /IGNORE LEADER

GO,     DCA CHKSUM
        TAD MEMTEM
        DCA MEMFLD
        TAD CHAR
        DCA WORD1
        JMS READ
        DCA WORD2
        JMS BEGG         /LOOK AHEAD
        JMP BEND         /TRAILER - END OF RECORD
        JMS ASSEMB
        SNL
        JMP MEMFLD
        DCA ORIGIN
CHEX,   TAD WORD1
        TAD WORD2
        TAD CHKSUM
        JMP GO
MEMFLD, 0
        DCA I ORIGIN
        ISZ ORIGIN
M200,   7600
        JMP CHEX
ASSEMB, 0
        TAD WORD1
        CLL RTL
        RTL
        RTL
        TAD WORD2
        JMP I ASSEMB
LORI,   JMP LOR
HIRI,   HIR-LOR
        0
WORD1=7776
WORD2,  0
EMASK,  6000
TMASK,  0001
TPRI,   HIR-TAPE
ADDR,   0
CHMSK,  0377


        *7777
        JMP BEGIN
$
```