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ABSTRACT

A general discussion of Dataway communication is presented followed by a description of the program sequences required to allow the NOVA computer to communicate with other computers on the Dataway. The Dataway sequences required to service terminals attached to the Dataway via Remote Teleprinter Interfaces are described. NOVA software developed to test the Dataway hardware is also described. The material presented here forms a basis for understanding Dataway communication and has proved invaluable for developing a new version of the ACL-NOVA system to support terminals attached to the Dataway via Remote Teleprinter Interfaces and to provide terminal users access to IBM360 disk storage.

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The following descriptors have been selected from the INIS Thesaurus to describe the subject content of this report for information retrieval purposes. For further details please refer to IAEA–INIS–12 (INIS: Manual for Indexing) and IAEA–INIS–13 (INIS: Thesaurus) published in Vienna by the International Atomic Energy Agency.

COMPUTER CODES; DATA TRANSMISSION; IBM COMPUTERS; INTERFACES; MAGNETIC DISKS; PROGRAMMING

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1. INTRODUCTION

The AAEC Dataway is a communication path that was designed to be independent of computers to be attached to it (Ellis 1970). It consists of a controller and a 15 quad cable (60 lines, each twisted quad consisting of two pairs) approximately half a mile in length having various entry points for the attachment of computers and certain specialised peripheral devices. Thirty seven lines of the cable are used as signal lines (the remaining lines being used as earth returns) with twenty seven lines being used to provide a 24-bit parallel data bus with a parity bit for each 8-bit byte, while four pairs of symmetrical, asynchronous control lines govern the data flow and status signalling over the Dataway (these are the Address In - Address Out, Hold In - Hold Out, Service In - Service Out, End In - End Out lines). The remaining two lines are used for monitoring the system.

Communication over the Dataway occurs between identical Dataway Control Units (C.G. Jones,AAEC unpublished report). Computers are attached to the Dataway by providing an interface between the computer and the Dataway Control Unit which translates the computer requests into the appropriate Dataway sequences. The interface should be designed to take advantage of program interrupt facilities and data channel access for data transfers and must conform to the input/output conventions of the computer. A different computer-DATAWAY interface is thus required for each type of computer on the Dataway.

Dataway communication between two computers occurs under program control, and software to handle Dataway operations must be written for each computer attached to the Dataway. However, low speed devices such as teletypewriter terminals require only a restricted set of Dataway sequences to transfer data. For these devices, a Remote Teleprinter Interface (Ellis, AAEC unpublished report) was designed to give fixed hardware responses to the required Dataway sequences.

The first computer on the AAEC Dataway was the NOVA computer which was connected via a NOVA-DATAWAY interface (C.G. Jones, AAEC unpublished report) and a Dataway Control Unit. The PDP9L computer was the next to be connected via a PDP9L-DATAWAY interface (C.G. Jones, AAEC unpublished report) and Dataway Control Unit. These were followed by the connection of an ASR33 teletypewriter terminal and an IE33 display terminal via two Remote Teleprinter Interfaces multiplexed from the one Dataway Control Unit. These terminals were set up to communicate with the NOVA computer.

A general discussion of Dataway communication is presented in Section 2 of this report, while the program sequences required to allow the NOVA computer to communicate with other computers on the Dataway are discussed in Section 3. Section 4 contains a discussion of the Remote Teleprinter Interface.

2. DATAWAY COMMUNICATION

2.1 General Discussion

The Dataway operates as a party line with two computers being able to communicate with each other if the Dataway is not currently in use. The communication occurs between a sending and receiving pair of Dataway Control Units and a number of fixed signalling sequences are available. When data transfer operations are required, the two control units go through an Initial Selection Sequence, a Data Transfer Sequence and an Ending Sequence as discussed in Section 2.2. Initial Selection Only sequences are used for transmission of status information when a data transfer sequence is not required or not possible (see Section 2.2.4).

The discussion presented in Section 2.2 is based on the signalling that would occur between two identical computers attached to Dataway Control Units via the same general computer-Dataway interface. These computers are assumed to have program interrupt facilities and data channel access to memory. The general computer-Dataway interface is assumed to have a Word Count Register, a Current Address Register, an Interrupt Register, and a 24-bit Buffer Register which is used to load the 24-bit Data Register and indirectly to load the 24-bit Address Register in the Dataway Control Unit. The Word Count and Current Address Registers are used in data transfer operations, and setting a bit in the Interrupt Register gives an interrupt to the computer. The computer is also assumed to have input/output instructions that can be used to access the interface registers and to send signals to raise the required Dataway control lines.

2.2 Dataway Sequences

Initial selection sequence. To begin Dataway communication, one of these identical computers must first call up the other computer over the party line when the line is not busy. The Initial Selection Sequence starts with the first computer (the sender) loading the Word Count and Current Address Registers (for a data transfer operation), and loading an Address Word into the Buffer Register. This computer now issues a'Raise Address Out' (RAO) signal to the interface to load the contents of the Buffer Register into the Data Register, into the Address Register and onto the Dataway data lines, and to raise the Address Out line. These signals travel along the Dataway and are received by every control unit attached to it. Each control unit loads the contents of the data lines into the Data Register and compares the address byte of the

Address Word with its own fixed address block and, if it makes a valid comparison, copies the Address Word into its Address Register, generates Address In (to signify that the addressed device is present and operational) and gives an 'Address Out' (AO) interrupt to the second computer. When the sending control unit receives the Address In signal, it drops the Address Out signal which consequently removes the Address Word from the data lines. This completes the address phase of the Initial Selection Sequence.

The 24-bit Address Word that must be loaded into the Buffer Register before signalling RAO consists of the 8-bit address of the required control unit as the high order byte (A0-A7), the 8-bit command byte as the middle byte (A8-A15), and the 8-bit address of the calling control unit (return address) in the low order byte (A16-A23). The eight bits of the command byte are:

Bit 0 - Variation
Bit 1 - Variation
Bit 2 - Variation
Bit 3 - Variation
Bit 4 - Variation
Bit 5 - Sense
Bit 6 - Read }
Bit 7 - Write } both on-Control

and they specify the function to be performed. A command byte consisting of all zeros is interpreted as a Test I/O command.

Once Address In is raised and the Address Out interrupt taken, the receiving computer should examine the request sent by the first computer by reading the contents of the Data Register. The contents of the Data and Address Registers are identical at Address Out time with the Address Word being kept in the Address Register during the whole Dataway sequence to allow the control unit to determine the reader and writer in the sequences that follow. If a data transfer is to take place, the second computer loads the Word Count and Current Address Registers and issues a 'Raise Hold Line' (RHL) signal to the interface to raise the Hold In line. The sending control unit responds to this by raising Hold Out which in turn drops Hold In when it is present at the receiving control unit. The raising of Hold Out after the Address In line is raised indicates that the Dataway has been successfully engaged and that data transmission may proceed.

When the Dataway is busy (that is, when the Address Out, Address In or Hold Out lines are raised) the interface does not load the contents of the

Buffer Register into the control unit registers and does not raise the Address Out line in response to the RAO signal. Instead, the interface gives a 'Repeat' (RPT) interrupt to the computer when the Dataway becomes free and the initial selection sequence must be repeated by loading the Word Count and Current Address Registers, loading the Address Word into the Buffer Register and issuing the RAO signal. If Address In is not raised in reply to Address Out within a certain period (approximately 50μs) during an initial selection sequence, then the required control unit is assumed to be off-line and the first computer is given a 'No Reply' (NRP) interrupt.

Data transfer sequence. When data is ready to be transferred, the Dataway has already been engaged and thus a valid Read or Write command must have been sent and accepted with both computers loading their Word Count and Current Address Registers. The sending and receiving control units mentioned in the section on initial selection sequence are now referred to as the reading and writing control units. Designation of a control unit as a reader or writer depends on the command required and whether it was the sender or receiver.

The successful engagement of the Dataway is used to generate a request to the reading control unit (determined by bit 15 of the Address Register) to indicate that it should now be ready to receive data. When ready, the reading control unit raises Service In which requests the writing control unit to send the first data word. Upon receipt of Service In, the writer updates its Word Count, uses the data channel to read the word pointed to by the Current Address (CA) Register into the Buffer Register, updates the CA Register, copies the contents of the Buffer Register into the Data Register and onto the data lines, and raises the Service Out line. The Service Out signal cancels the Service In when received by the reading control unit. This control unit loads the data word from the data lines into the Data Register, uses a data channel read to store the data in the word pointed to by the CA register, updates the Word Count (WC) Register and CA Register and raises Service In to indicate that it is ready for the next word of data. This Service In drops Service Out when it is present at the writing control unit and the data word is removed from the data lines. The writing control unit subsequently raises Service Out to load the next word onto the Dataway.

The Service In - Service Out responses alternate until either the reading control unit has received the data it requires (its WC overflows) or the writing control unit has transmitted all of its data (it gets a WC overflow) and the corresponding computer is given an 'Overflow' (OF) interrupt. With equal word counts, the reader is always given the Overflow interrupt. Once the data transfer is completed in this way, the only remaining operation is to disengage the Dataway.

Ending sequence. Dataway operations can be terminated either by the reader or the writer and during the ending sequence each is given the opportunity to send status and error information to the other. The actual ending sequence depends on which control unit terminated the Dataway operation, although both possible sequences are quite symmetrical. Figs. 1 and 2 show schematic diagrams for Read and Write sequences respectively (where the original WC set by each computer is identical) and they give examples of the sender and receiver termination discussed below.

In the case of sender termination (see Figure 1) the status and error information is loaded into the Buffer Register and the 'Raise End Line' (REL) signal issued to the interface to load the contents of the Buffer Register into the Data Register and onto the data lines, and to raise the End Out line. End Out automatically lowers any Service requests present on the Dataway and, when present at the receiving control unit, the contents of the data lines are loaded into the Data Register and an 'End Line' (EL) interrupt is given to the computer. The receiving computer can read the status from the Data Register and then load its own status and error information into the Buffer Register and issue the REL signal to load the contents of the Buffer Register into the Data Register and onto the data lines and to raise the End In signal. Since the receiving computer has now received and sent ending status it now issues a 'Terminates' (CTS) signal to the interface and this causes the Address In line to drop. When End In is detected by the sending control unit, End Out is cleared automatically, the contents of the data lines are loaded into the Data Register and an End Line interrupt given to the computer. The sending computer can read the ending status from the Data Register and then issue a Terminates signal to the interface to conclude Dataway operations; this results in the Hold Out line dropping which causes the End In line to drop. The Dataway now becomes free.

The case of receiver termination is very similar (see Fig. 2), with each computer exchanging ending status before terminating, so there is no need to describe it in detail here.

The 24-bit ending status that can be sent to each computer is too large for present requirements so the low order byte (D16-D23) is used as a status byte, while the middle byte is used to present sense code information for communication with the PDP9L computer (Richardson 1973). The bit assignments for the status byte are:

Bit 0 - Attention

Bit 1 - Status Modifier

Bit 2 - Control Unit End

Bit 3 - Busy

Bit 4 - Channel End

Bit 5 - Device End

Bit 6 - Unit Check

Bit 7 - Unit Exception

and these (and the bit assignments of the command byte) are identical to the bit assignments used for status (and commands) in the IBM360 computer.

Initial selection only. The Initial Selection Only sequence is used when the command can be satisfied without transfer of data such as requests to present (request) status information to (from) another computer. This sequence is also the default sequence when the receiving computer is busy and cannot proceed with the command specified in the Address Word.

Initial Selection Only is identical to the initial selection sequence during the Address Out - Address In phase of operation except that the CA and WC Registers do not have to be loaded if a data transfer operation is not required (see Fig. 3). After the receiving computer is given an Address Out interrupt and it examines the Address Word in the Data Register, the appropriate status information is loaded into the Buffer Register and an REL signal issued to the interface to load the contents of the Buffer Register into the Data Register and onto the data lines and to raise the End In line. When End In is received by the sending control unit the contents of the data lines are loaded into the Data Register and an End Line interrupt given to the computer. The sending computer can read the ending status and then load its own status information into the Buffer Register and issue an REL signal to the interface to load the contents of the Buffer Register into the Data Register and onto the data lines, and to raise the End Out signal. The Terminates signal (CTS) is now issued to free the sending control unit.

When End Out is detected by the receiving control unit, End In is cleared automatically, the contents of the data lines are loaded into the Data Register and an End Line interrupt given to the computer. The receiving computer can read the ending status and then issue a Terminate signal to complete the Dataway sequence; this results in the Address In line dropping which causes the End Out line to drop.

Dataway error flag. There is a Dataway error flag associated with each control unit that can be tested to see if a parity error has occurred during the transfer of data or the presentation of ending status. This means that if a reader receives the Overflow interrupt during a data transfer operation, then the Dataway error flag can be tested to check for any errors in the data received and the appropriate ending status compiled. In this case the data transfer operation should be repeated. If the setting of the Dataway error flag to indicate that there is at least one parity error in the data block transmitted is not considered to be a sufficient check for a particular application, then some form of checksum should be included with the data.

The status received at End Line interrupt time can also be checked using the Dataway error flag and Test I/O sequences used to obtain the correct status if necessary. However, if the writer receives the Overflow interrupt during a data transfer operation, then there is no point in checking the Dataway error flag before sending ending status since the data is only checked for parity errors when received by the reader. In this case, if the Dataway error flag is set when the reader gets an End Line interrupt there is no way of distinguishing whether the error occurred during the transmission of data or the presentation of status and the data transfer operation should be repeated.

Time out. If two computers are communicating over the Dataway and a reply is not received from one of the computers because it has gone into a non-interruptable state or has become non-operational then the Dataway may be hung up. These hangups may not be permanent but would exclude all other prospective users for an indefinite time.

To cope with this problem a Dataway Monitor Unit is attached to the Dataway and contains a time-out counter, sequence gates, line terminators and a disconnect generator. If a reply to some part of a Dataway operation is not received within the time-out period (approximately 800 μs) then a Disconnect signal is issued to all control units to free the Dataway. All active computers receive a 'Disconnect' (DCN) interrupt (with all pending interrupts being cleared) and the sending computer should restart the initial selection sequence.

3. THE NOVA-DATAWAY INTERFACE

3.1 General Discussion

The NOVA computer is attached to the AAEC Dataway via a NOVA-DATAWAY interface and Dataway Control Unit. The NOVA-DATAWAY interface is connected to the I/O bus of the NOVA computer and is designed to take advantage of the NOVA's program interrupt and fast data channel facilities.

The interface contains a 7-bit Interrupt Register, a 16-bit Word Count Register, a 16-bit Current Address Register and a 24-bit Buffer Register.

The interface responds to input/output instructions with device codes $(32)_8$ and $(33)_8$ that are used to access the registers in the interface, to send signals to the interface to raise certain Dataway control lines, and to access the 24-bit Data Register and 24-bit Address Register in the Dataway Control Unit. These instructions, the NOVA interrupt facilities and a sample Dataway sequence for the NOVA are discussed below.

3.2 NOVA Instructions

For each 6-bit device code used an interface attached to the NOVA computer has available to it three basic input instructions (DIA, DIB, DIC), three basic output instructions (DOA, DOB, DOC), a No I/O transfer instruction (NIO), Busy and Done Flags with associated skip instructions to test them, and an Interrupt Disable flag. In addition three different signals (S, C, P) can be issued with each of these I/O instructions.

However, to provide enough instructions to load (using output instructions) and read (using input instructions) the various interface and control unit registers it is necessary to use two device codes, namely, $(32)_8$ and $(33)_8$. The S, C, P signals for each of these device codes are used to indicate that certain Dataway control lines are to be raised. The particular Dataway control lines coupled to the S, C, P signals were carefully chosen to allow for combined I/O instructions. For example to load the high order bytes of the Buffer Register and to issue the RAO signal required that the LHD n and the corresponding C pulse used the same device code. The Done and Busy flags for device code $(32)_8$ are used in conjunction with skip conditions to test for the presence of a Dataway interrupt with Interrupt Off conditions and to test the Dataway error flag respectively.

The final set of I/O instructions (and the associated instruction mnemonics) chosen for the NOVA-DATAWAY interface are described in detail in Appendix A. The way in which these instructions are used will become apparent from the discussion presented below.

3.3 Dataway Interrupts

There are seven Dataway conditions that can interrupt the NOVA computer. If Priority line 8 (Interrupt Disable flag bit 8) is enabled then the interrupt is taken and device code $(32)_8$ is given in response to an Interrupt Acknowledge (INTA n) instruction. The condition causing the interrupt is determined by using the 'Read Interrupt Register' instruction (RIR ≡ DIA n, $(33)_8$) to read a 3-bit code that corresponds to the highest priority interrupt set in the Interrupt Register. The computer can subsequently use the same 3-bit code to clear the interrupt condition by using a 'Clear Interrupt

Register' instruction (CIR n $\equiv$ DOA n,$(33)_8$). The various Dataway interrupts (in their priority order) and the corresponding 3-bit codes are described in detail in Appendix B.

The 3-bit Dataway interrupt code can be used conveniently, with an indexed table branch to pass control to the routine that handles that particular interrupt, as shown in the following set of NOVA instructions:

```
WAIT      SKPIRN                   Skip if Dataway interrupt present
          JMP        *-1           Otherwise, check again
          RIR        0             Read interrupt code into ACO
          CIR        0             Clear interrupt condition
          LDA        3,TBLPTR      Load A(TBL-1)
          ADD        0,3           Point to correct table entry
          JSR   I    0(3)          Branch to appropriate routine
          JMP        WAIT          Return to waiting loop
TBLPTR    DC         A(TBL-1)
TBL       DC         A(DCN)        Disconnect
          DC         A(NRP)        No Reply
          DC         A(RPT)        Repeat
          DC         A(AO)         Address Out
          DC         A(SO)         Service Out
          DC         A(EL)         End Line
          DC         A(OF)         Overflow
```

The example shown applies to Interrupt Off conditions and assumes that the routines that handle the Dataway interrupts are subroutines.

3.4 Dataway Read Sequence Between Two NOVA Computers

To demonstrate the way in which the NOVA I/O instructions are used in Dataway operations, the example given here is that of one NOVA computer with the address X'48' reading 400 words (800 bytes) of information into locations A to A+399 from locations B to B+399 of a second NOVA computer with the address X'4A'. Appropriate interrupt handlers that pass control to routines that process the Dataway interrupts are assumed to be in each computer and the response to be given for the appropriate Dataway interrupt is discussed below.

The initial selection sequence begins with the first NOVA computer setting its Word Count Register to 400 using the SWC n instruction, setting its Current Address Register to A using SCA n, loading the Address Word X'4A0248' into the Buffer Register and issuing the RAO signal to the interface by using the LLD n and RDS n (LHD n + RAO) instructions.

Assuming the Dataway is free and the second NOVA computer is on-line, then the second NOVA computer receives an Address Out interrupt. This computer checks the address of the calling computer by making use of the RLD n instruction, and then uses the RCB n instruction in checking the command. The receiver now uses the SCA n and SDT n (SWC n + RHL) instructions to set its Current Address to B, its Word Count to 400 and to issue the RHL signal to start the data transfer sequence.

The data transfer sequence concludes with the sending NOVA computer (see Fig. 1) receiving an Overflow interrupt. This computer tests the Dataway error flag using a skip condition (SKPDEZ or SKPDEN) and sends appropriate ending status using the LHD n and SES n (LLD n + REL) instructions.

The second NOVA computer now receives an End Line interrupt and reads the first computer's status using the RHD n and RLD n instructions. This computer now sends its ending status and terminates using the LHD n, SES n and CTS instructions.

An End Line interrupt is now received by the first computer which terminates Dataway operations using the CTS instruction after reading the second computer's status with the RHD n and RLD n instructions.

4. THE REMOTE TELEPRINTER INTERFACE

4.1 General Discussion

A restricted set of Dataway sequences applies to devices that require one byte or character of information per operation at a rate that is slow compared with the capacity of the Dataway. Blocking of information using these devices must purposely be restricted to prevent engaging the Dataway for exceedingly long periods of time.

The only storage these devices have is used to handle the current character. No provision is made for storing return addresses so each of these devices is tied to a particular calling address and the Dataway sequences are modified so that it can only communicate with this address. Therefore the return address byte is redundant and can be replaced with a data byte or character. The computer that would normally be communicating with such a device uses the address byte of the Address Word sent by the device to calculate the address byte that should be used when calling up the device. This type of operation reduces the required activity on the Dataway because the initial selection sequence is now a pseudo data transfer sequence.

To handle a number of teletypewriter terminals on the Dataway this idea is further extended (Ellis,AAEC unpublished report) by having an interface for each terminal (the Remote Teleprinter Interface), that is designed to communicate with only one computer (Dataway address), multiplexed from one

Dataway Control Unit that can reply to a block of Dataway addresses.

4.2 Dataway Sequences

The Remote Teleprinter Interface is designed to minimise the number of Dataway sequences required to control the attached terminal. To send output to the terminal, for example, the computer issues an initial Write command containing the first data byte. When this character is printed, the terminal issues a Read command indicating that it is ready to print the next character. By loading the next output character into the Buffer Register and issuing the 'Raise Service Line' signal to the computer interface at the Address Out time, as shown schematically in Fig. 5, the output can be sent to the terminal with one Dataway sequence per character. When all the data has been sent to the terminal, the computer replies with normal ending status and must later begin with a Write sequence to send more output to the terminal. The schematic diagrams in Figs. 4, 5 and 6 show the Dataway sequences used in sending output to the terminal via the Remote Teleprinter Interface. The interface responses are hardwired and they are drawn as computer software sequences for convenience only. Appendix C contains a flow diagram showing the hardware responses of the Remote Teleprinter Interface to the different Dataway sequences.

It is possible for computers to simulate the actions of the Remote Teleprinter Interface. This would allow the monitor terminal on one computer to be used to access a system running on another computer (such as the ACL-NOVA system).

Input from the terminal can be received as the result of a Read sequence issued by the computer or a Write sequence issued by the terminal. When this character is received by the terminal, either at Service Out time (Fig. 7) or Address Out time (Fig. 9), then the ending status sent by the computer can be used to control the paper tape reader. If Channel End, Device End status is given (and the paper tape reader is on) then successive Write sequences from the terminal send more input to the computer. The sending of Channel End status on its own is used to idle the paper tape reader. Of course, the pressing of a keyboard character at the terminal always causes a Write sequence to be sent to the computer. The schematic diagrams shown in Figs. 7, 8 and 9 show the different Dataway sequences used in obtaining input from a terminal. A Test I/O sequence can also be initiated by the computer to test the status of the teletypewriter reader or printer.

5. NOVA SOFTWARE

5.1 Introduction

NOVA software was initially set up to test the operation of the NOVA I/O instructions to be used for Dataway operations and to test Dataway sequences between the NOVA and PDP9L computers (Jones, AAEC unpublished report). This was followed by the development of a special version of the ACL-NOVA system, ACLNOVAD, designed to allow Dataway testing to proceed while ACL-NOVA was available at the various teletypewriter terminals around site.

Later, the Remote Teleprinter Interface was designed and test programs were developed to check its operation. The ACLNOVAD program was further modified to include testing of a number of terminals attached to the Dataway via Remote Teleprinter Interfaces (see Section 5.3).

5.2 Tests Carried Out on the Remote Teleprinter Interface

Two programs were developed to test terminals attached to the Dataway via the Remote Teleprinter Interface. The first program, RCUTESTH, was designed to echo characters sent from the terminal and to save all the information that was sent to the terminal or all the information that came from the terminal in a 'history buffer'. The contents of the history buffer proved to be very useful in the initial testing stages.

A second test program, RCUTESTS, was developed to test the paper tape reader/punch by punching the characters X'FF' to X'01' on paper tape continuously while reading characters from this paper tape output and checking that they were read (and punched) correctly. This program 'hammered' the one character per Dataway sequence operation by keeping the paper tape reader and paper tape punch operating continuously.

5.3 The ACLNOVAD Program

A version of the ACL-NOVA system, ACLNOVAD, was set up to allow ACL-NOVA to be used at five teletypewriter terminals while Dataway tests were being carried out. At the same time, the ACLNOVAD program allowed the Tektronix T4002 Graphical Display terminal attached to the NOVA computer to display unusual Dataway conditions or to be used as an ODT (Octal Debugging Technique) facility for changing the data used in the Dataway sequences. The current version of ACLNOVAD allows input typed at either of the two terminals attached to the Dataway via Remote Teleprinter Interfaces to be echoed while Dataway sequences between the PDP9L computer (or another computer) and the NOVA computer take place and at the same time supports five other teletypewriter terminals under the ACL-NOVA system.

The ACLNOVAD program uses $7\frac{3}{4}$K words in the NOVA computer (an extra 1K words) leaving 4K words for the ACL-NOVA work areas. The Dataway operations are handled entirely under Interrupt, with a special routine in the NOVA computer processing the interrupts from the Dataway and from the Tektronix display and passing any other interrupts to the ACL-NOVA interrupt handler.

The only other modification made to the normal ACL-NOVA system was to allow Dataway Interrupts always to be enabled.

6. CONCLUSIONS

The work covered by this report is a fundamental part of the work done in setting up the AAEC Dataway. With the completion of the PDP9L-NOVA link the NOVA computer became the first Dataway computer to have access to the resources of the IBM360 computer (Sanger and Backstrom 1973) and this has already allowed IBM360 programs to interact with the Tektronix Display terminal attached to the NOVA computer (Backstrom and Sanger 1973), thus providing the first example of interactive Dataway computing.

A new version of the ACL-NOVA system is currently being developed to support terminals attached to the Dataway via the Remote Teleprinter Interface and to provide terminal users access to IBM360 disk storage. The techniques described in this report have proved invaluable in the development of this software and have already been used extensively in all the Dataway software that has been written for the NOVA computer.

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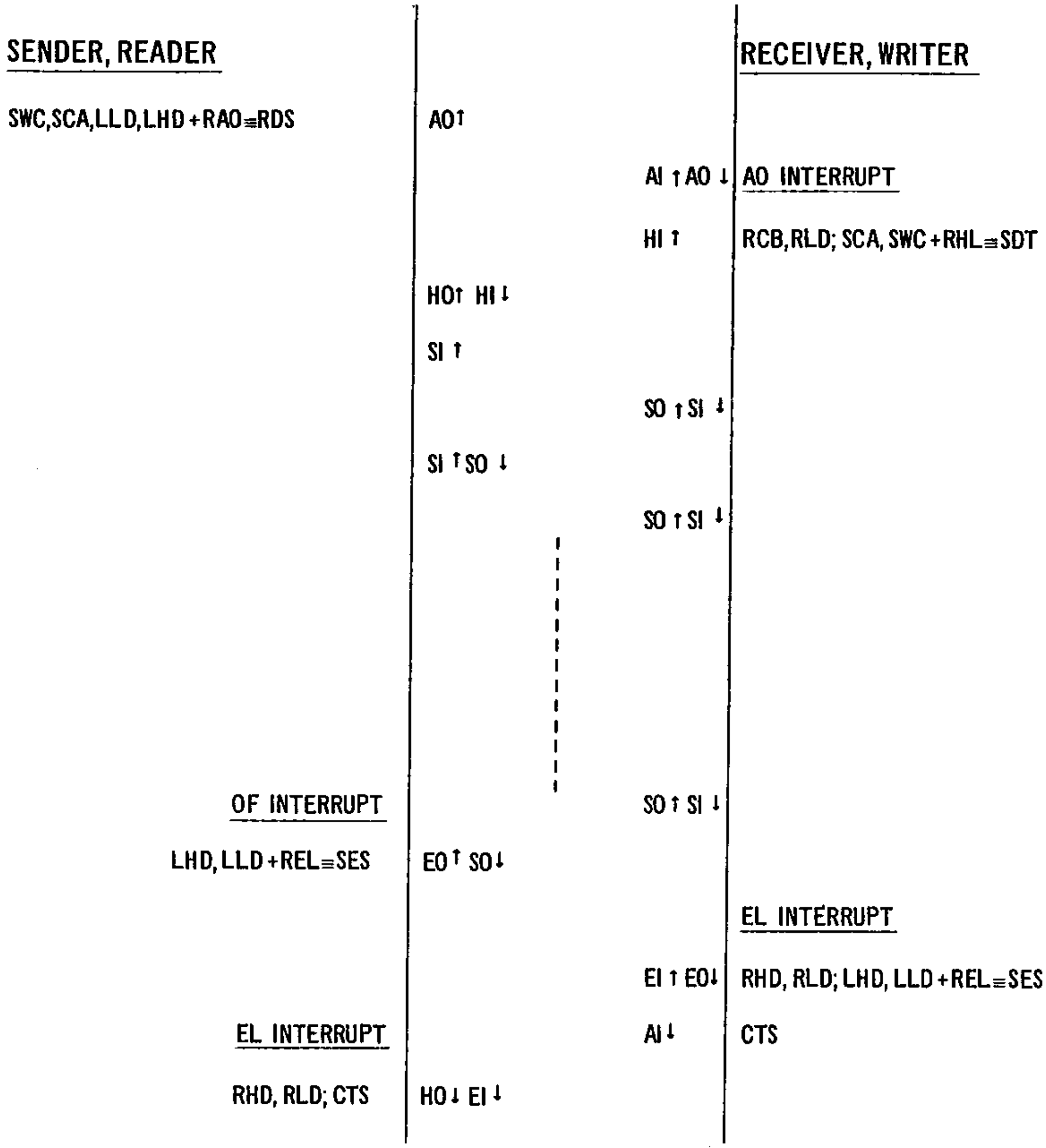


FIGURE 1 DATAWAY READ SEQUENCE (WORD COUNTS IDENTICAL)

SENDER, WRITER			RECEIVER, READER
SWC, SCA, LLD, LHD + RAO ≡ RDS	AO↑		
		AI↑ AO↓	AO INTERRUPT
		HI↑	RCB, RLD; SCA, SWC + RHL ≡ SDT
	HO↑ HI↓		
		SI↑	
	SO↑ SI↓		
		SI↑ SO↓	
	SO↑ SI↓		
	⋮		
	SO↑ SI↓		
			OF INTERRUPT
		EI↑ SO↓	LHD, LLD + REL ≡ SES
EL INTERRUPT			
RHD, RLD; LHD, LLD + REL ≡ SES	EO↑ EI↓		
CTS	HO↓		EL INTERRUPT
		AI↓ EO↓	RHD, RLD; CTS

FIGURE 2 DATAWAY WRITE SEQUENCE (WORD COUNTS IDENTICAL)

SENDER			RECEIVER
LLD, LHD + RAO ≡ RDS	AO↑		
		AI ↑ AO ↓	AO INTERRUPT
		EI ↑	RCB, RLD; LHD, LLD + REL ≡ SES
EL INTERRUPT			
RHD, RLD; LHD, LLD + REL ≡ SES CTS	EO ↑ EI ↓		
			EL INTERRUPT
		AI ↓ EO ↓	RHD, RLD; CTS

FIGURE 3 DATAWAY TEST I/O SEQUENCE

NOVA			RTI
LLD, LHD + RAO≡RDS	AO↑		
		AI↑ AO↓	AO INTERRUPT
		EI↑	RAB, RCB, RLD; LHD, LLD + REL≡SES
EL INTERRUPT			(character in return address) (CE STATUS)
RLD; LHD, LLD + REL≡SES	EO↑ EI↓		
(CE STATUS) CTS			EL INTERRUPT
		AI↓ EO↓	RLD; CTS

FIGURE 4 WRITE SEQUENCE TO REMOTE TELEPRINTER INTERFACE

NOVA			RTI
		AO↑	LLD, LHD + RAO≡RDS
AO INTERRUPT	AI↑ AO↓		
RCB, RAB; LHD, LLD, RSL	SO↑		
(character ready)			
			SO INTERRUPT
		EO↑ SO↓	RLD; LHD, LLD + REL≡SES
EL INTERRUPT			CTS (character in low byte) (CE STATUS)
RLD; CTS	AI↓ EO↓		

FIGURE 5 READ SEQUENCE FROM REMOTE TELEPRINTER INTERFACE (CHARACTER READY)

NOVA			RTI
		AO↑	LLD, LHD+RAO≡RDS
AO INTERRUPT	AI↑ AO↓		
RCB, RAB; LHD, LLD+REL≡SES	EI↑		
(character not ready) (CE, DE status)			EL INTERRUPT
		EO↑ EI↓	RHD, RLD; LHD, LLD+REL≡SES
EL INTERRUPT			CTS (CE status)
RHD, RLD; CTS	AI↓ EO↓		

FIGURE 6. READ SEQUENCE FROM REMOTE TELEPRINTER INTERFACE (CHARACTER NOT READY)

NOVA			RTI
LLD, LHD+RAO≡RDS	AO↑		
		AI↑ AO↓	AO INTERRUPT
		SO↑	RCB, RAB; LHD, LLD, RSL
			(character ready)
SO INTERRUPT			
RDL; LHD, LLD+REL≡SES	EO↑ SO↓		
(character in low byte) (CE status) CTS			EL INTERRUPT
		AI↓ EO↓	RLD; CTS

FIGURE 7 READ SEQUENCE TO REMOTE TELEPRINTER INTERFACE (CHARACTER READY)

NOVA			RTI
LLD, LHD + RAO ≡ RDS	AO ↑		
		AI ↑ AO ↓	AO INTERRUPT
		EI ↑	RCB, RAB; LHD, LLD + REL ≡ SES
EL INTERRUPT			(character not ready) (Busy status)
RHD, RLD; LHD, LLD + REL ≡ SES	EO ↑ EI ↓		
(CE status) CTS			EL INTERRUPT
		AI ↓ EO ↓	RHD, RLD; CTS

FIGURE 8 READ SEQUENCE TO REMOTE TELEPRINTER INTERFACE (CHARACTER NOT READY)

NOVA			RTI
		AO ↑	LLD, LHD + RAO ≡ RDS
AO INTERRUPT	AI ↑ AO ↓		
RAB, RCB, RLD; LHD, LLD + REL ≡ SES	EI ↑		
(character in return address) (CE, DE status to keep paper tape reader moving, otherwise CE status)			EL INTERRUPT
		EO ↑ EI ↓	RLD; LHD, LLD + REL ≡ SES
EL INTERRUPT			CTS (CE status)
RLD; CTS	AI ↓ EO ↓		

FIGURE 9 WRITE SEQUENCE FROM REMOTE TELEPRINTER INTERFACE

APPENDIX A

NOVA I/O INSTRUCTIONS FOR THE DATAWAY

The NOVA-DATAWAY interface uses the device codes $(32)_8$ and $(33)_8$ and these are referred to as DW1 and DW2 respectively in the instruction mnemonics defined below:

DATA TRANSFER INSTRUCTIONS

READ HIGH DATA (RHD n ≡ DIA n,DW1)

The two high order bytes of the Data Register (D0-D15) are read into accumulator n.

READ LOW DATA (RLD n ≡ DIB n,DW1)

The low order byte of the Data Register (D16-D23) is read into the low order byte of accumulator n. The remaining high order bits are set to zero; this applies below to all read instructions that do not load 2 bytes into an accumulator.

READ ADDRESS BYTE (RAB n ≡ DIC n,DW1)

The high order byte of the Data Register (D0-D7) is read into the low order byte of accumulator n. When an Address Out interrupt is received, this byte corresponds to the address byte of the Address Word (the Data Register and Address Register are identical at Address Out time).

READ COMMAND BYTE (RCB n ≡ DIB n,DW2)

The middle byte of the Data Register (D8-D15) is read into the low order byte of accumulator n. When an Address Out interrupt is received, this byte corresponds to the command byte of the Address Word.

LOAD HIGH DATA (LHD n ≡ DOA n,DW1)

The contents of accumulator n are loaded into the two high order bytes of the Buffer Register (B0-B15).

LOAD LOW DATA (LLD n ≡ DOB n,DW1)

The contents of the low order byte of accumulator n are loaded into the low order byte of the Buffer Register (B16-B23)

LOAD ADDRESS BYTE (LAB n ≡ DOC n,DW1)

The contents of the low order byte of accumulator n are loaded into the high order byte of the Buffer Register (B0-B7)

SET WORD COUNT (SWC n ≡ DOC n,DW2)

The contents of accumulator n are loaded into the Word Count Register. A positive word count must be specified.

SET CURRENT ADDRESS (SCA n ≡ DOB n,DW2)

The contents of accumulator n are loaded into the Current Address Register.

In data transfer sequences, the Current Address Register is incremented after the first memory location is referenced.

READ CURRENT ADDRESS (RCA n ≡ DIC n,DW2)

The contents of the Current Address Register are read into accumulator n. When an Overflow (OF) interrupt occurs at the end of a data transfer sequence, the CA Register contains the sum of the original CA and the original WC.

READ INTERRUPT REGISTER (RIR n ≡ DIA n,DW2)

The 3-bit code used to identify an interrupt (see Appendix B) is read into the low order 3 bits of accumulator n.

CLEAR INTERRUPT REGISTER (CIR n ≡ DOA n,DW2)

The interrupt condition corresponding to the code in the low order 3 bits of accumulator n is cleared. The Interrupt Register is completely cleared if bit zero of accumulator n is set to one, or if an I/O Reset (IORST) instruction is executed.

CONTROL INSTRUCTIONS

RAISE ADDRESS OUT (RAO ≡ NIOC DW1)

A Clear pulse from device code $(32)_8$ is sent to the NOVA-DATAWAY interface and if the Dataway is not busy, the contents of the Buffer Register are copied into the Data Register and the Address Register, loaded onto the data lines and the Address Out line raised to request Dataway service.

RAISE HOLD LINE (RHL ≡ NIOC DW2)

A Clear pulse from device code$(33)_8$ is sent to the NOVA-DATAWAY interface to raise Hold In in response to a request for a data transfer sequence. The word count and current address required for the data transfer should have previously been set using SWC n and SCA n instructions.

RAISE SERVICE LINE (RSL ≡ NIOS DW1)

A Start pulse from device code $(32)_8$ is sent to the NOVA-DATAWAY interface to raise the appropriate Service Line and if the NOVA is the Writer, the contents of the Buffer Register are copied into the Data Register and loaded onto the data lines. This instruction can be used to continue a data transfer sequence, but is normally used for Restricted Control Unit operations.

RAISE END LINE (REL ≡ NIOP DW1)

A 'P' pulse from device code $(32)_8$ is sent to the NOVA-DATAWAY interface to raise the appropriate End Line, and the contents of the Buffer Register are copied into the Data Register and loaded onto the data lines.

COMPUTER TERMINATES (CTS ≡ NIOP DW2)

A 'P' pulse from device code $(33)_8$ is sent to the NOVA-DATAWAY interface to reset the Address In or Hold Out lines to complete the Dataway ending sequence.

COMBINED INSTRUCTIONS

REQUEST DATAWAY SERVICE (RDS n ≡ RAO + LHD n = DOAC n,DW1)

The contents of accumulator n are loaded into the two high order bytes of the Buffer Register and a Clear pulse from device code $(32)_8$ is then sent to the NOVA-DATAWAY interface. If the Dataway is not busy, the contents of the Buffer Register are copied into the Data Register and the Address Register, loaded onto the data lines and the Address Out line raised to request Dataway service.

LOAD ADDRESS BYTE AND REQUEST DATAWAY SERVICE
(LARDS n ≡ RAO + LAB n ≡ DOCC n,DW1)

If the address byte and command byte of the Address Word are to be loaded separately, then LHD n followed by LARDS n must be used instead of RDS n.

SEND ENDING STATUS (SES n ≡ REL + LLD n ≡ DOBP n,DW1)

START DATA TRANSFER (SDT n ≡ RHL + SWC n ≡ DOCC n,DW2)

SET CURRENT ADDRESS AND START DATA TRANSFER
(SCADT n ≡ RHL + SCA n ≡ DOBC n,DW2)

SKIP INSTRUCTIONS

SKIP IF INTERRUPT REGISTER ZERO (SKPIRZ ≡ SKPDZ DW1)

SKIP IF INTERRUPT REGISTER NONZERO (SKPIRN ≡ SKPDN DW1)

SKIP IF DATAWAY ERROR FLAG ZERO (SKPDEZ ≡ SKPBZ DW1)

SKIP IF DATAWAY ERROR FLAG NONZERO (SKPDEN ≡ SKPBN DW1)

SUMMARY

Instruction Mnemonic	Instruction Code (n = 0)	
	Octal	Hexadecimal
RHD n ≡ DIA n,DW1	060432	611A
RLD n ≡ DIB n,DW1	061432	631A
RAB n ≡ DIC n,DW1	062432	651A
RIR n ≡ DIA n,DW2	060433	611B
RCB n ≡ DIB n,DW2	061433	631B
RCA n ≡ DIC n,DW2	062433	651B
LHD n ≡ DOA n,DW1	061032	621A
LLD n ≡ DOB n,DW1	062032	641A
LAB n ≡ DOC n,DW1	063032	661A
CIR n ≡ DOA n,DW2	061033	621B
SCA n ≡ DOB n,DW2	062033	641B
SWC n ≡ DOC n,DW2	063033	661B
RSL ≡ NIOS DW1	060132	605A
RAO ≡ NIOC DW1	060232	609A
REL ≡ NIOP DW1	060332	60DA
RHL ≡ NIOC DW2	060233	609B
CTS ≡ NIOP DW2	060333	60DB
RDS n ≡ RAO + LHD n ≡ DOAC n,DW1	061232	629A
LARDS n ≡ RAO + LAB n ≡ DOCC n,DW1	063232	669A
SES n ≡ REL + LLD n ≡ DOBP n,DW1	062332	64DA
SDT n ≡ RHL + SWC n ≡ DOCC n,DW2	063233	669B
SCADT n ≡ RHL + SCA n ≡ DOBC n,DW2	062233	649B
SKPIRZ ≡ SKPDZ DW1	063732	67DA
SKPIRN ≡ SKPDN DW1	063632	679A
SKPDEZ ≡ SKPBZ DW1	063532	675A
SKPDEN ≡ SKPBN DW1	063432	671A

APPENDIX B

NOVA INTERRUPTS FROM THE DATAWAY

The seven Dataway conditions that can give interrupts to the NOVA computer and the corresponding 3-bit codes are described below in order of priority:

DISCONNECT (DCN = 001)

A faulty sequence of responses has caused the Dataway Control Unit to be made not active as a result of a time-out condition. The DCN signal clears all pending Dataway interrupts before giving an interrupt to the NOVA computer. If the NOVA computer initiated the Dataway sequence, then the DCN interrupt should be cleared and the request for Dataway service repeated by loading the Word Count, Current Address and Buffer Registers and executing the RAO instruction. Otherwise, the DCN interrupt should just be cleared and normal background processing continued until the other Dataway computer restarts the Dataway sequence.

REPEAT (RPT = 010)

The NOVA computer executed the RAO instruction to request Dataway service, but was unsuccessful due to the Dataway being busy or due to interference on the lines. The RPT interrupt indicates that the Dataway has become free and the request for Dataway service can be repeated by loading the Word Count, Current Address and Buffer Registers and executing the RAO instruction.

NO REPLY (NRP = 011)

The NOVA computer executed the RAO instruction to request Dataway service, but no Dataway Control Unit raised the Address In line within the allowed time-out period due to the required Dataway Control Unit being off-line or not operational. A NRP interrupt is also given to the NOVA computer if the NOVA's Dataway Control Unit is off-line.

ADDRESS OUT (AO = 100)

A request for service has been received by the NOVA's Dataway Control Unit and the corresponding Address Word is available in the Data Register. If a data transfer sequence is required, then the Word Count and Current Address Registers should be loaded and the RHL instruction executed. Otherwise, immediate ending status should be given by loading the Buffer Register and executing the REL instruction.

SERVICE OUT (SO = 101)

A word of data has been received from a Restricted Control Unit on request from the NOVA computer. The data word is available in the Data

Register. Appropriate ending status should be sent by the NOVA computer by loading the Buffer Register and executing the REL instruction, and the CTS instruction executed to complete the Dataway sequence.

END LINE (EL = 110)

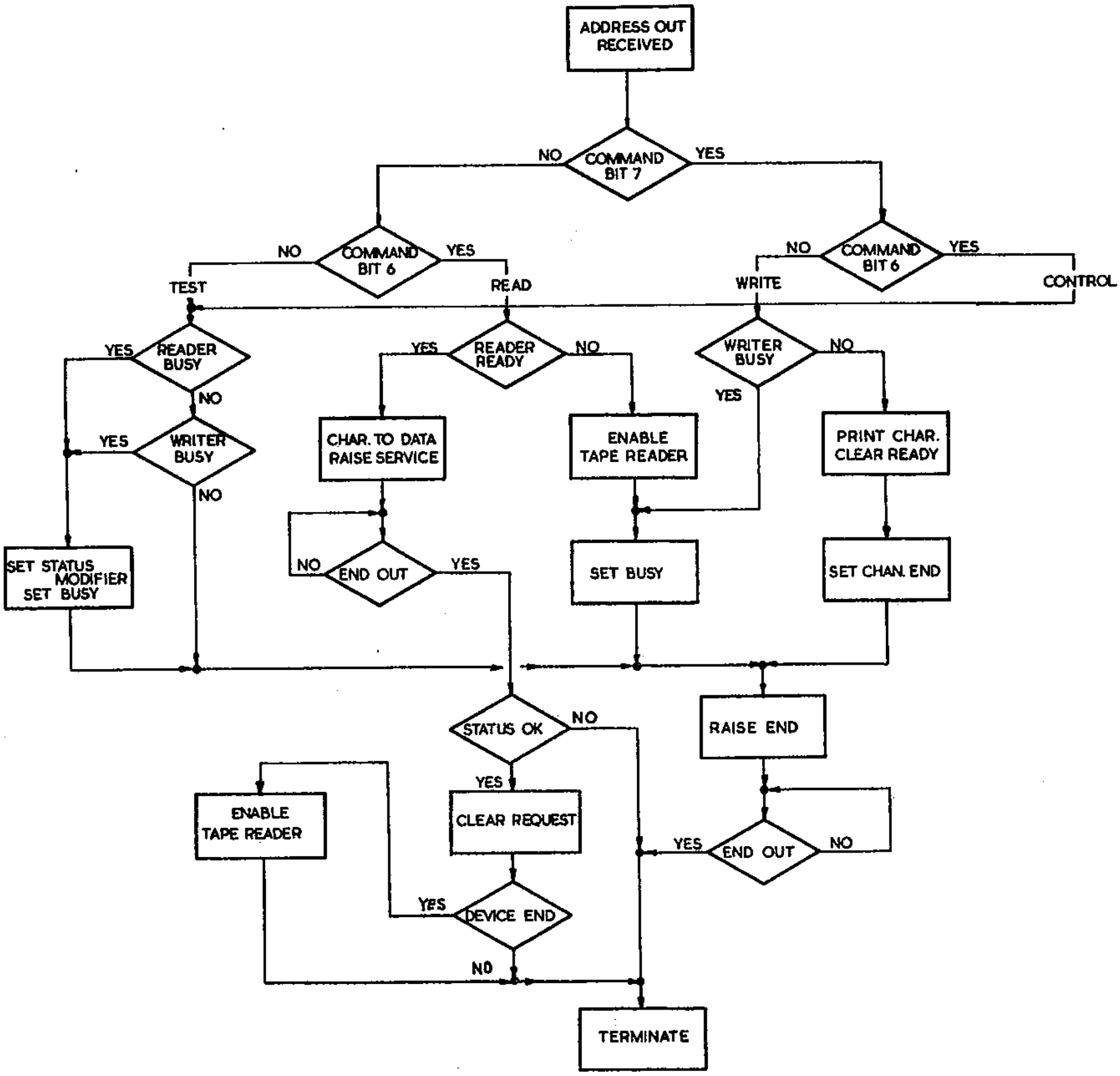
An ending signal, End In or End Out, has been received from another Dataway Control Unit and corresponding ending status is available in the Data Register. If the NOVA computer has already sent ending status, then the CTS instruction should be executed to complete the Dataway sequence. Otherwise, ending status should be sent by loading the Buffer Register and executing the REL instruction, before executing the CTS instruction to complete the Dataway sequence.

OVERFLOW (OF = 111)

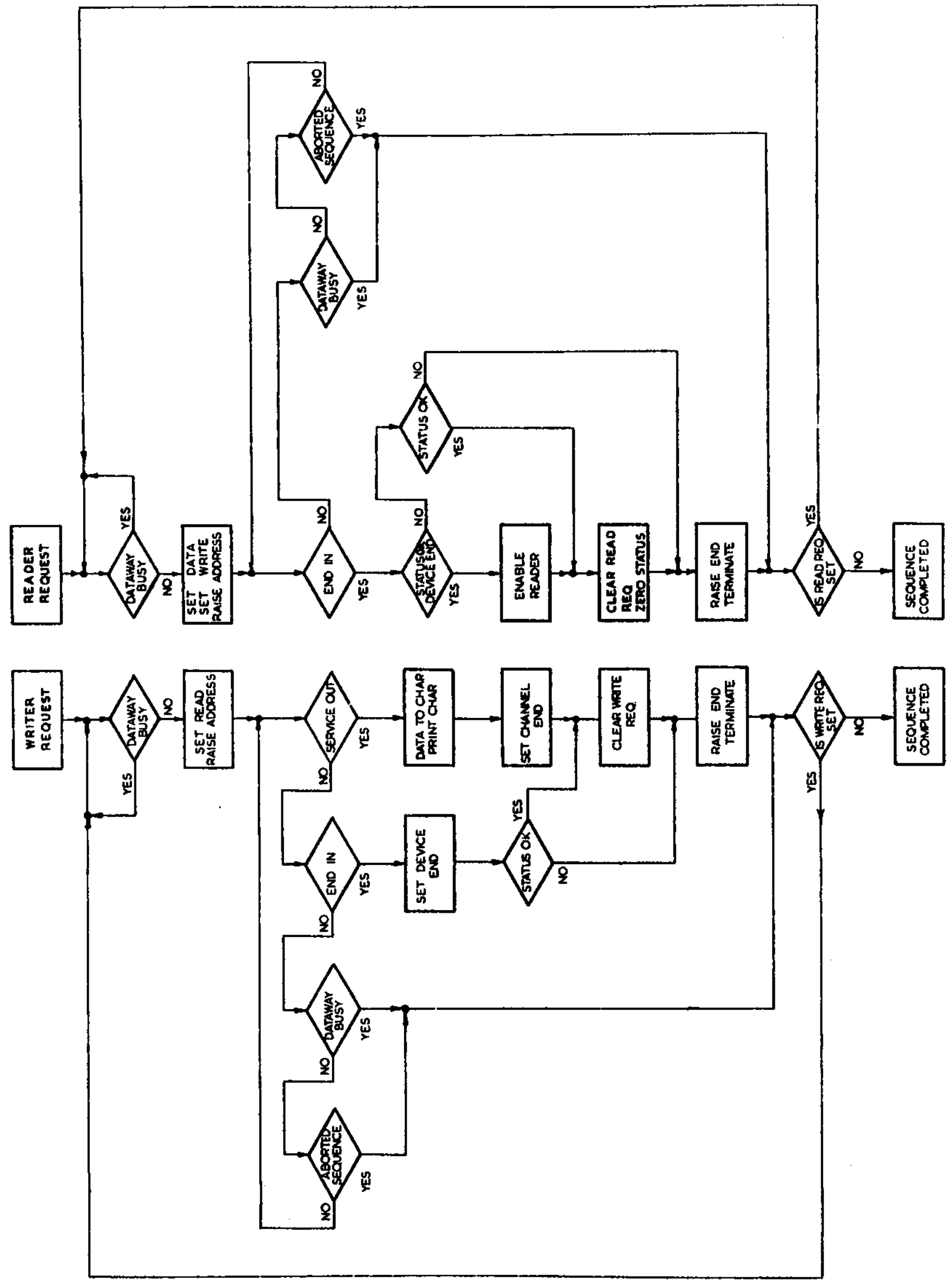
The Word Count Register has reduced to zero in a data transfer sequence. If the NOVA computer is the Reader, then the Dataway Error Flag should be checked before sending ending status. Otherwise, normal ending status should be given by loading the Buffer Register and executing the REL instruction.

APPENDIX C

FLOW DIAGRAMS OF HARDWARE RESPONSES OF THE REMOTE TELEPRINTER INTERFACE



REMOTE TELEPRINTER DATAWAY INITIATED RESPONSES



REMOTE TELEPRINTER DEVICE INITIATED RESPONSES