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Data Handling System for the Bendix G-15D Digital Computer

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ABSTRACT

This report describes methods and equipment used for transferring experimental data into a digital computer (Bendix G-15D). The data is obtained at remote field stations by sampling, encoding, and storing in digital form on magnetic tape, signals obtained during experiments concerning underwater sound. The computer is used for correlation studies and other statistical analyses.

The system described includes provision for the reading of continuous field tapes into the computer, selection of data by means of visual display, and an x-y plot of results. Details of hardware and programs using the G-15D computer as central processor are discussed.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

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DATA HANDLING SYSTEM FOR THE BENDIX G-15D DIGITAL COMPUTER

INTRODUCTION

The Electronics Branch is doing research on the fundamental statistical characteristics of signals and noise in underwater acoustic propagation. The analysis requires accurate recording of field data, accurate fast handling and mathematical processing of large volumes of short-word data, and plot-out of answers for further selection, analysis, and predictions (1).

In the laboratory, data must be selected from the field tapes for computer processing. In all cases, the data has been sampled and encoded as digital numbers, recorded on magnetic tape, and brought back to the laboratory for processing. The field recording system has been described in a previous report (2).

The data handling system is integrated with the processing system (computer) and is considered to be the most efficient and economical system, based upon the nature of our problem. This requires versatile, fast transfer of field data into memory, ease of selection using a visual monitor (3,4), statistical analysis, and a plot-out of data under program control (5).

This report is concerned primarily with the hardware and software associated with data handling for the Bendix G-15D digital computer. Figure 1 is a photograph of the basic parts of the data handling system. These are from left to right, the x-y plotter, visual monitor oscilloscope, field data tape unit, and a rack containing the digital control electronics, along with two magnetic core buffers and power supply.

Figure 2 is a photo of the entire system with the Bendix G-15D computer and its two auxiliary tape units.

The functional aspects of the system are first discussed in conjunction with a general block diagram, followed by a more detailed description of the individual components and programs.

GENERAL DESCRIPTION OF DATA HANDLING SYSTEM

There are four basic functions of the Data Handling System, hereafter referred to as (DHS). These functions are provisions for: (a) entry of collected experimental data into a digital computer, (b) selection of specific data for computation, (c) performance of statistical analysis on selected data, and (d) display of results of the computations for human observation and analysis. Associated with each stage are particular requirements dictated by a specific format of the data, characteristics of available hardware, particular type of mathematical analysis being performed, and desired form of output.

Hardware

A block diagram, Fig. 3, shows the basic functional blocks or units. The flow of data through the system will be traced to illustrate the function of each unit. The hardware can be further reduced into two basic categories involving data controls and data handling or storage.

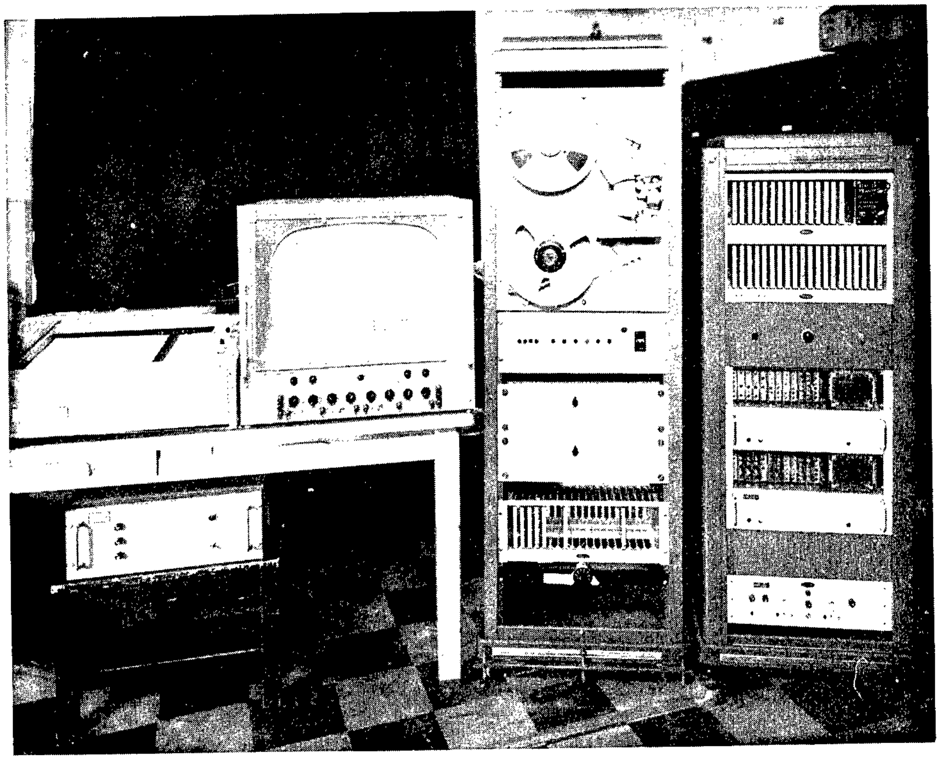

Fig. 1 - Hardware for data handling system. From left to right: the x-y plotter, visual monitor oscilloscope, field data tape unit, and a rack containing the digital control electronics, along with two magnetic core buffers and power supply.

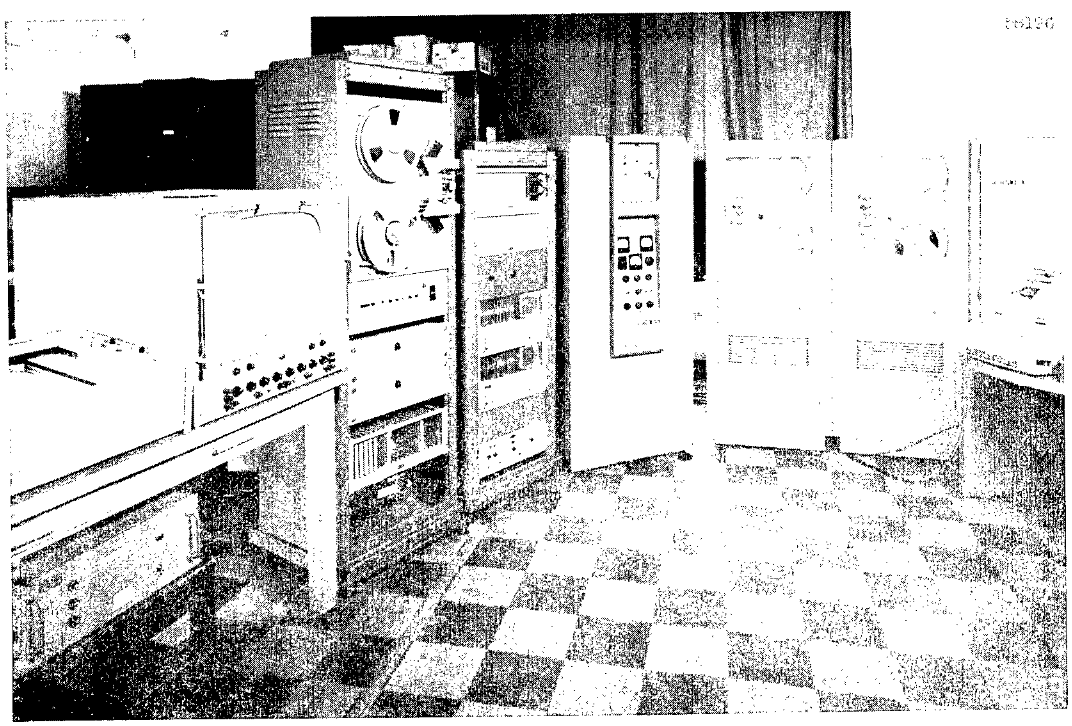

Fig. 2 - Data handling system with central processing computer

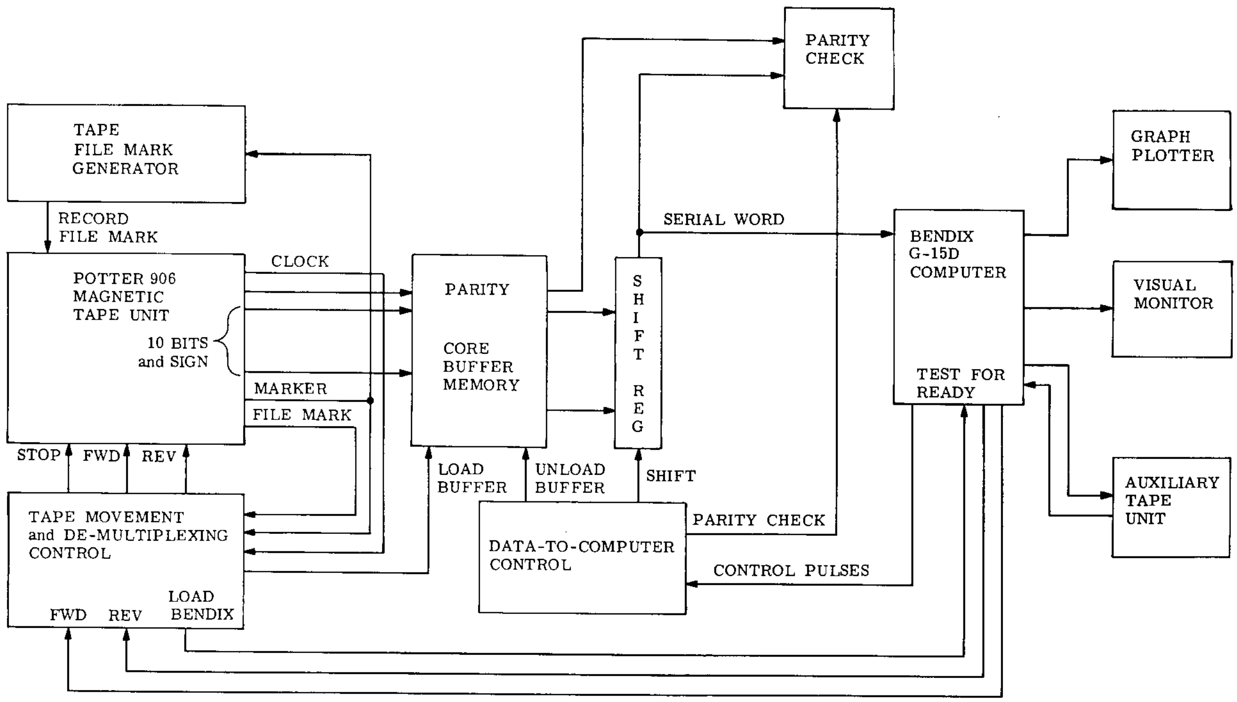

Fig. 3 - Block diagram of data handling system

The data storage is primarily concerned with the transfer of data from the field tape unit into the G-15D computer, supplemented with a visual monitor to check data integrity, a graph plotter to plot out the mathematical results, and an on-line magnetic tape unit for bulk storage (6,7). Input data is supplied to the system via a 16-channel digital magnetic tape unit (Fig. 3).

Because of differences between transfer rates of the magnetic tape and the drum storage in the computer, an intermediate storage unit is used. Transfers are made in a two step cycle: the core buffer is loaded from tape and then while the tape is stopped, data is transferred by way of a shift register from the buffer to the drum memory of the computer. Associated with the transfer into the computer is a parity check circuit.

The visual monitor is used for the selection of data before computation. The display requires recycling of readout from memory in sequence of a block of data for display on an oscilloscope via a digital-to-analog converter. Programmed options allow the operator to determine which portions of the computer memory will be monitored, thereby enabling observation and selection by displayed waveform of data of interest for computation (8).

The auxiliary magnetic tape unit is used to supplement the limited storage of the computer. Data selected via the DHS is stored on this tape unit for later computation. This tape unit also serves as permanent storage for the computed results, and therefore acts as an input-output device.

Results of computations can be printed out on the typewriter that is a standard input-output unit of the computer. However, the plotted output is desired in some of the mathematical results and is achieved by means of an x-y plotter. Details of the x-y plotter are discussed in a separate report (5).

The control circuits automatically sequence the data transfers previously described. The logic modules used were made by Navigation Computer Corporation (Navcor "300" Series). Operation of the system as diagrammed on Fig. 3 can be described as follows.

The magnetic tapes are recorded in the field as essentially continuous records in order to avoid undesirable complication of field equipment necessary to preserve all of a signal sequence and still insert record gaps on the tape. A means was required for breaking up the long records into usable size for computer use, still preserving complete integrity of the data and allowing for tape unit start-stop times. This provision is made by recording a file mark pulse at fixed intervals in an available channel on the tape. The tape file code generator records this signal at one-hundred-word intervals and can be operated independently of the computer. Recording the file marks* necessitates a separate pass of the magnetic tape.

The tape movement and demultiplexing control is another item of interest. This section serves to start and stop the tape unit in either forward or reverse mode via pulses from the computer. The demultiplexing section selects what word groups are to be read from tape into the buffer temporary storage.

The data-to-computer control sequences the data from the buffer store, implementing a parallel-to-serial transfer from buffer to computer via a shift register, and, in addition, runs the data through the parity check circuit.

The alternation of this load and dump cycle is under control of signals from the computer, and this procedure allows transfer of data from an asynchronous tape unit to a computer.

Software

As previously mentioned, all operations of the DHS are initiated and sequenced through stored programs in the computer. By typing codes on the input typewriter, the operator indicates to the computer which operations are to be performed.

The DHS program consists of seven basic subroutines plus a code recognizer to provide for subroutine selections by code. When the operator types one of the specific codes on the input typewriter, the recognizer uses this code as the address part of a jump command to enter the desired routine. Following are brief descriptions of each subroutine.

<u>Type Check Sums (TOO)†</u> – This routine allows the operator to have the check sum of each file‡ typed out after it has been read into the computer. This is useful for identifying files on data tape. If at a later date, the operator should desire to locate a particular file, he can use its check sum as a means of identification.

<u>Read Data Tape (±Unn)</u> – This subroutine controls the transfer of data from the magnetic tape playback unit to the memory of the computer. The sign part of the typed-in code determines which direction the tape moves when it is read (plus for forward, minus for reverse).

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*File marks are now generated at the time of data recording in the field.

†The symbols in parentheses are the codes for manual selection via typewriter keyboard of the given subroutine.

‡The term "file" is used to describe a complete block of data on a data tape. Although there is no physical record gap between "files," there is however a "file mark" between them. A "file mark" is a pulse recorded in a separate channel on the data tape. A "file" consists of 100-word groups as a matter of convenience for programming.

Visual Monitor (VOO) – The visual monitor allows the analog representation of data in the computer memory to be visually scanned. Words are sequentially transferred to a flip-flop storage register and transformed to analog representation by a digital-to-analog converter. By connecting the output of the converter to an oscilloscope, the data can be visually scanned.

Write on Library Tape (WOO) – This routine permits selected data from memory to be recorded on the standard Bendix MTA-2 magnetic tape unit. Thus, a permanent recording of selected data is available for future use. Recorded with the data is a "record number." A log book of "record numbers" is maintained by the operator for retrieval of specific tape records with the "Search Library Tape" routine.

Search Data Tape (±XOO) – This routine allows the operator to automatically relocate a particular block of data on the field tape. It does this by locating a block of data with the same check sum as the operator supplied to the program. The direction of tape movement is determined by the sign code as mentioned in the "read data tape" routine.

Search Library Tape (YOO) – When records are written on the library tape, a record number is recorded along with the data. The record numbers are arranged by the operator to be sequential. By utilizing these facts, this routine can automatically locate any record on a library tape. It does so by reading the nearest record number and subtracting it from a record number supplied by the operator. The results of the subtraction indicate to the program how far and in what direction it must move the tape to reach the desired record, and the program executes this operation.

Read Library Tape (Z08 or Z17) – By typing Z08 or Z17, the operator can use either eight or seventeen lines of a record on tape to be read and stored in the computer. During the reading process, the check sum of each of the lines is checked for verification. If the check sum of a line is not correct, repeated attempts to read the entire record will be made.

DETAILED DESCRIPTION OF DATA HANDLING SYSTEM

Hardware

The first item of interest in the hardware is the digital magnetic recorder that contains the field data. This recorder is a Potter 906 four-speed, 16-channel, single-head recorder with manual and remote control. The data has been recorded with a packing density of 267 bits per inch, corresponding to an 8-kc transfer rate at a speed of 30 ips (inches per second). The data can be multiplexed up to 8 channels giving a transfer rate of 1 kc per data channel.

Figure 4 illustrates the tape format used in this system. The binary coded data, 10-bits plus sign, are recorded in channels 3 through 14 with the exception of channel 9 which contains the clock.

The term "channel" has been used without clarification and it might be instructive to clarify this point. When applied to the tape unit, there are 16 channels or tracks (Fig. 4); when applied to the data, there are eight different analog input channels. Each data channel has been sampled, encoded, and the codes placed laterally onto the 16 tape channels with all the additional information as shown. When all eight data channels have been encoded and written on tape, they comprise a sample group, and a "group marker" bit is written on the tape to identify them.

The marker bit is located in tape channel 16. The file mark is located in tape channel 2 and has been inserted after each 100 sample groups. The function of the file mark will

FUNCTION	TAPE CHANNEL (TRACK)	MULTIPLEXER CHANNEL NO. SAMPLE GROUP (N) 1 2 3 4 5 6 7 8		SAMPLE GROUP (N+1) 1 2 3 4 5 6 7 8
SPARE CHANNEL	1	0 0 0 0 0 0 0 0		0 0 0 0 0 0 0 0
FILE MARK	2		1	
2^0	3	1 1 0 1 0 0 1 0		1 1 0 0 0 1 1 1
2^1	4	0 0 1 1 0 0 0 1		1 1 1 1 0 1 1 0
2^2	5	0 0 0 0 1 1 0 1		0 1 1 0 0 1 0 1
2^3	6	1 1 0 0 1 0 1 1		1 0 0 1 0 1 1 0
2^4	7	1 0 1 1 0 0 0 1		1 0 1 0 1 1 0 0
2^5	8	0 1 0 0 1 0 1 1		1 0 1 1 1 0 0 1
CLOCK	9	1 1 1 1 1 1 1 1		1 1 1 1 1 1 1 1
2^6	10	1 1 0 1 0 0 1 1		0 1 1 1 0 0 0 1
2^7	11	0 1 0 0 1 1 0 1		0 1 1 0 0 0 1 0
2^8	12	0 0 1 1 0 1 0 0		1 1 0 1 0 1 0 0
2^9	13	0 0 0 1 1 1 0 0		1 0 1 1 0 0 1 0
SIGN	14	1 0 1 1 1 0 0 1		0 0 0 1 1 0 1 1
ODD PARITY	15	0 0 1 0 1 1 1 1		0 1 0 0 0 1 1 0
MARKER	16	1 0 0 0 0 0 0 0		1 0 0 0 0 0 0 0

Fig. 4 - Magnetic tape format showing eight data channels multiplexed on a 16-channel tape

be explained in more detail in a later section. The parity bit is located in channel 15 and is an odd parity bit associated with the recorded data. Channel 1 is an unused data channel or spare.

Usually the file mark is recorded at the time the data is obtained in the field. In the event there is no file mark on a data tape, there is provision for generating one in the laboratory using the file mark generator (Fig. 3) that is part of the DHS. The function of the file mark is to break up the continuous data into discrete blocks. The file mark is a pulse dubbed in between every 100 marker pulses on a separate tape channel. This allows data to be transferred by blocks into the computer via the buffer.

The file mark generator is made up of a ten-stage binary counter, an "and" gate, preset toggle switches, a delay unit, and the tape recorder write amplifier for channel 2.

Writing file marks in the laboratory requires reading a data tape not containing file marks, and having the file marks written into tape channel 2. This is accomplished by reading the data tape and feeding the marker pulses into the binary counter. The binary counter counts the number of markers read, and after a selected number have been read, as determined by the preset toggle switches feeding the "and" gate, a pulse will be generated. This pulse is delayed for an appropriate length of time so that it is not written coincident with the data bits, but is written in between marker pulses. Since this is a single head recorder, a special cable is used allowing information to be written in channel 2 only, all other channels remaining in a read mode.

Once the tape has file marks, data can then be read into the buffer core memory. This core memory allows for an asynchronous operation between field tape unit and computer. Two buffers are used in parallel to give a 16-bit word length and a total of 144 words. The purpose of these units is to accommodate the differences in rates of information flow of the field tape recorder and the digital computer. Information is loaded in parallel (11 bits per data word), and on receipt of external pulses, the address is advanced by magnetic stepping switches contained in the buffer. The file mark and parity bit are also stored in the buffer for control and check purposes respectively.

Loading of data to the buffer is coordinated with operation of the computer by means of pulse generation and signal sensing instructions within the computer program. Because of the limited storage capacity of the core memory, the load buffer cycle and transfer to computer cycles, must be restricted to data blocks of one hundred words representing one of the eight possible data channels between successive file marks (called one file).

The sequencing of operations necessary to load the buffer is accomplished by the "tape movement and demultiplexing control" in conjunction with the computer program (Fig. 3). Initiating signals and resulting actions for loading one file to the buffer (see flow chart, Fig. 5) occur in the following order: a computer instruction code generates a signal on the "forward" line. Tape movement begins and playback of signals from tape is underway. The first file mark signal to occur clears the address counter of the buffer to all

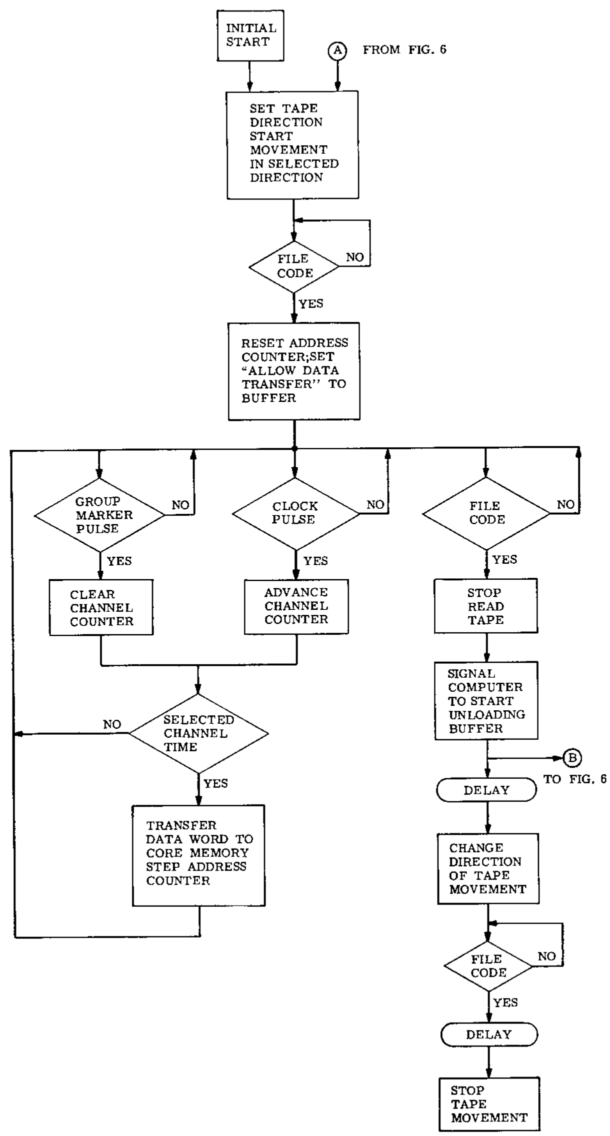


Fig. 5 - Loading of buffer store from field tape

zeroes and activates control circuits which allow transfer of data to proceed. Demultiplexing is accomplished by gating for transfer, only those words which occur at times determined by the state of a 3-stage binary counter connected to the clock pulse channel from tape. The counter is synchronized with the data channel sequence by being reset to zero by the group marker pulse. Inputs from the counter to the load buffer gate are selected by a manual rotary switch to decode the binary states for the data channel desired.

At the time a word is determined to be available for transfer, a load buffer signal occurs and the information on the data lines is gated into the buffer memory storage. The address counter is advanced by a delayed signal following the store cycle and the entire cycle is repeated until another file mark is read. At that time, 100 words will have been transferred to the buffer store because there are 100 word groups between successive file marks.

When the file mark is read, data transfers and tape movement are stopped and a signal is sent to the computer and sensed by a "test for ready" instruction. The program tallies the number of files that have been transferred and changes to the transfer-from-buffer-to-computer cycle.

Because of the time lags involved in tape start and stop, the tape is in an incorrect position for reading the next file of data at the end of reading one file. The file mark which terminates the transfer to buffer operation, therefore, also causes tape movement to reverse; when the file mark is again read from tape, a delayed stop tape is generated which positions tape for the next transfer to buffer.

When the core buffer storage has been loaded with 100 words, representing one block of data between file marks, a "ready" signal is sent from the control circuit and the computer goes into a program that controls the transfer of data from buffer to computer storage.

This process of data transfer to the computer must be gated to the write circuits of the drum, with clock pulses from the computer. The sequence for data transfer operates in the following manner (see flow diagram, Fig. 6). The computer initiates a pulse to clear the buffer address counter and also clears the shift register. Another pulse is sent from the computer to transfer one data word in parallel into the shift register. A string of pulses from the computer then shifts the data serially out of the shift register onto the drum. The computer program will continue this process of parallel-to-serial transfer from buffer to computer via the shift register, until the entire block of data, representing 100 data words, has been loaded into the computer.

One hundred data words have been loaded onto the drum in successive order during one revolution of the drum. This process accomplished a parallel-to-serial transfer of each word, and the timing derived from computer signals insured a proper location on the drum. During the process of data transfer to the computer, each data word was also checked for odd-parity errors.

The computer is now ready to either start processing the data or call for more from the field data tape unit. The number of blocks of data to be read into the computer depends on the programmer. Each block of data will load one line with 100 words on the drum storage, although a line has a capacity of 108 words. When the required amount of data has been stored in the computer, the programmer can make a visual inspection of the data using the "Visual Monitor" (3).

Parity Check – During the transfer of data from the core memory to the computer, a check is made for consistency between data and the associated parity bit. Data was encoded and recorded on the magnetic tape with odd parity and transferred to the buffer in the same format.

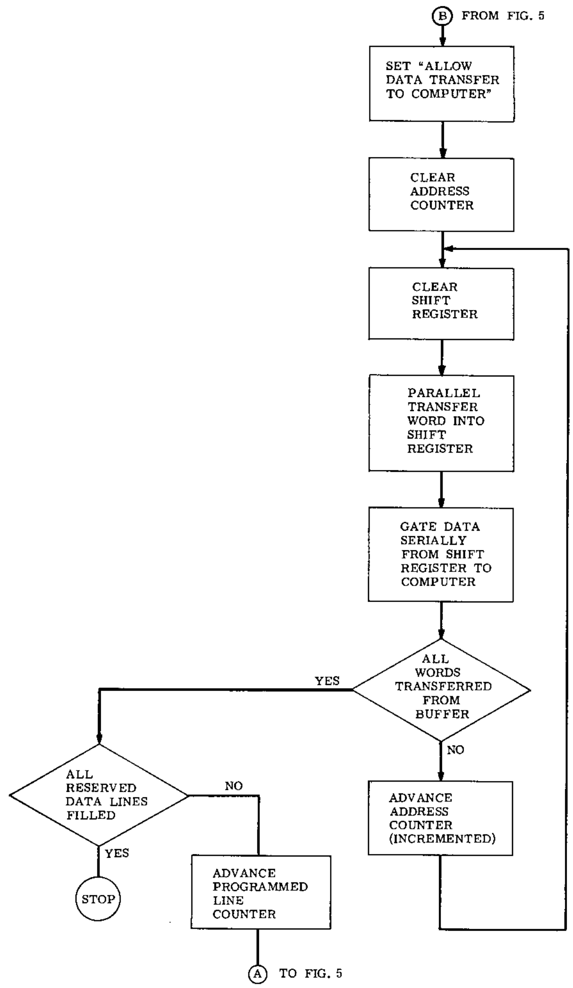


Fig. 6 - Transfer from buffer to computer

Controls for the check circuit are readily derived from pulses used for transferring each word to the computer. A complementing flip-flop is used as a binary scaler for "ones" that are shifted into the computer memory. The flip-flop is set to the "one" state by a pulse from the computer just prior to read out from the core memory; a reset occurs if the parity bit readout is a "one." After binary scaling of the flip-flop during the shifting operation by data "ones," the final state is tested by a reset pulse from the computer. If the flip-flop is not already reset when tested, a pulse is generated which advances a counter to tally the total errors. No automatic feedback to the computer is provided, so if errors occur, intervention is left to the discretion of the operator. It should be pointed out that an operator is normally present during the transfer to computer from data tape.

Software

All operations previously discussed concerning the hardware are initiated and sequenced through stored programs in the computer. Selection of the desired subroutine is accomplished by keying a specific code to the program "recognizer" by typewriter. Tab-S on the typewriter then initiates a transfer to the first instruction of the selected subroutine.

Recognizer – *The DHS program is composed of a code recognizer and seven subroutines, one for each function that can be performed by the system. When the operator types one of the designated subroutine codes, the recognizer interprets this code and initiates the selected subroutine.

The operation of the recognizer is as follows (see the flow diagram, Fig. 7). Completion of the code type-in is signaled to the computer by typing TAB-S. The three least significant digits of the code are extracted and transferred to the "AR" register. The extracted bits are shifted left four places and added to the N-portion of a skeleton command. Subsequent operations of this command effect an unconditional program jump to the instruction at the address specified by the value of N. At the selected address is the first command of the desired subroutine.

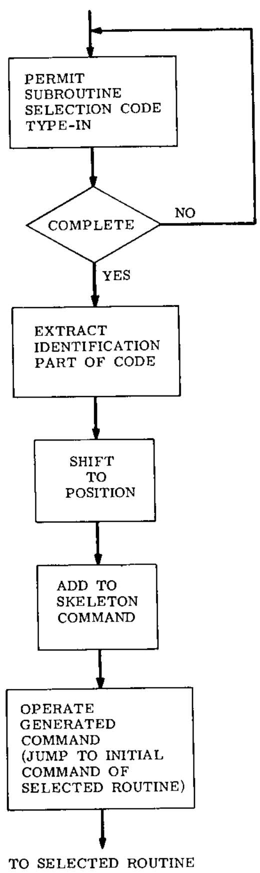


Fig. 7 - Recognizer

Type Check Sums (TOO) – This routine allows the operator to have the check sum of each block of data or file typed out after it has been read into the computer. This check sum is computed automatically by the computer and facilitates locating a particular file and checking it for accuracy.

The operation of the check sum is as follows (see the flow diagram, Fig. 8). First, control words for format selection are transferred into the standard computer program for typing out contents of arithmetic register (AR) to prepare for typing the check sums as they are computed. An accumulative addition of the 100 data words in one line around the drum (line 02) is then performed during one revolution, the final result remaining in the arithmetic register. The result is typed out, address of line to be summed is incremented by one, and a test is made to determine whether all seventeen check sums have been completed. The conditional jump either returns to the program location for summing the next line, or signals completion by ringing the computer bell and returning to the recognizer routine to await the type-in of another code by the operator.

Read Data Tape (±Unn) – This subroutine controls transfer of data from the magnetic field tape playback unit to the memory of the computer. The subroutine causes the computer to supply a pulse to the data transfer unit which in turn causes the tape on the field tape unit to move in a selected direction. The program immediately goes into a "test state" to await a signal from the transfer unit. Under control of the transfer unit, a file of data is read from the field tape and stored in the buffer core memory. When this operation is completed, the transfer unit sends a signal to the program and the program initiates the transfer of the data from the buffer memory to the computer drum memory.

The sign portion of the typed code determines which direction the tape will move for reading. A positive sign will read the tape forward, a minus sign in reverse. The "nn" portion of the code is a decimal number between the limits 00 to 99 that determines how many files will be read into the computer.

*An attempt will be made to keep discussion of the programs in general terms, although some knowledge of the Bendix G-15D programming would be conducive to ease of understanding.

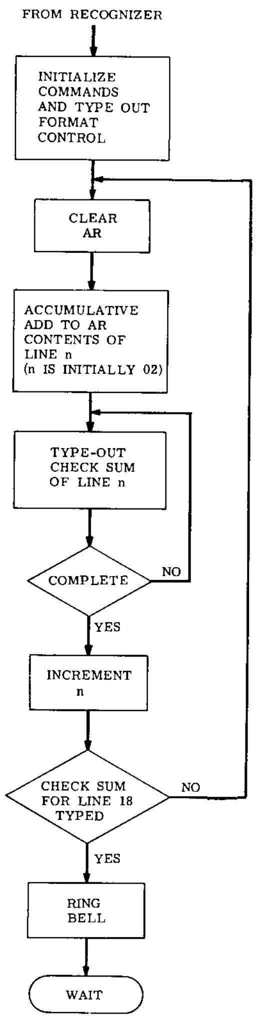


Fig. 8 - Type check sums (TOO)

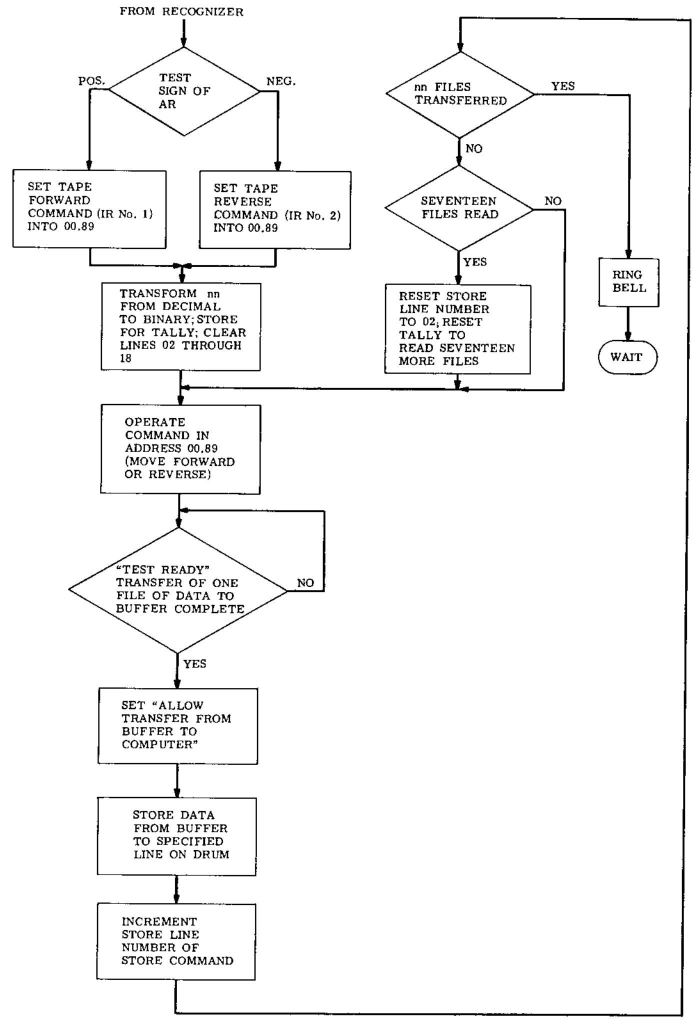


Fig. 9 - Read data tape (±Unn)

The flow diagram (Fig. 9) indicates the sequence of operations during this program. The sign of the selection code typed in by the operator is tested and the corresponding tape movement command is placed in an address forming a part of the subroutine sequence. The value of "nn" is also converted from decimal to binary form and stored as a test number for controlling the program loop.

The move tape is initiated, and control of the transfer to the intermediate storage buffer is taken over by hardware previously described. Sequencing of this data transfer is accomplished by signals derived from pulses on tape, in particular, the playback of the file mark, clock, and marker channels.

The computer repeats the "test ready" instruction until a signal is received from the "tape movement and demultiplexing control" at the time that transfer of one file to the buffer is completed and tape movement is stopped. The program then causes generation of a signal which activates gates allowing pulses from the drum to control a parallel to serial conversion and transfer into a program-selected line of the drum memory. The word length of the data is ten bits and sign so that parallel read out to a shift register can be easily accomplished during the unused bit times of the G-15 word of twenty-eight bits and sign. Extractor signals set up by the program are used for shifting and gating data to the drum at proper times.

After the transfer from buffer to drum is completed in one drum revolution, the line number for storage access is incremented and a test is made to determine if "nn" files have been transferred. If so, the program terminates and waits for action by the operator. If "nn" files have not been transferred, a test of whether seventeen files have been transferred is made. The resulting action is to set up conditions for either storing the next file of data in the next line (line number just incremented), or in the initial line (02) of the seventeen lines reserved for data storage. In either case, the program continues looping back to the move tape command until "nn" files have been transferred. It should be noted that for normal sequential storage of data, "nn" should be an integral multiple of seventeen.

Visual Monitor (VOO) – The visual monitor allows the quantized digital data stored in the computer to be visually scanned (3). The monitor basically operates as follows: data lines 02 through 18 are successively transferred to line 19. By using extractors previously stored in AR, the visual monitor transfers the data in line 19, one word at a time into an external shift register. On completion of the serial transfer of each data word, a parallel transfer is made from the shift register to a flip-flop storage. The digital number in the flip-flop storage is transformed to its quantized analog representation by a digital-analog converter, or ladder network. By connecting the output of the converter to an oscilloscope, the data can be visually scanned.

The program loop diagrammed on the flow chart (Fig. 10) maintains the transfer of data into line 19 for display. A pulse for triggering the oscilloscope sweep is generated just prior to the transfer of the initial line of data (line 02). Block commands are used for transferring a full line per revolution of the drum.

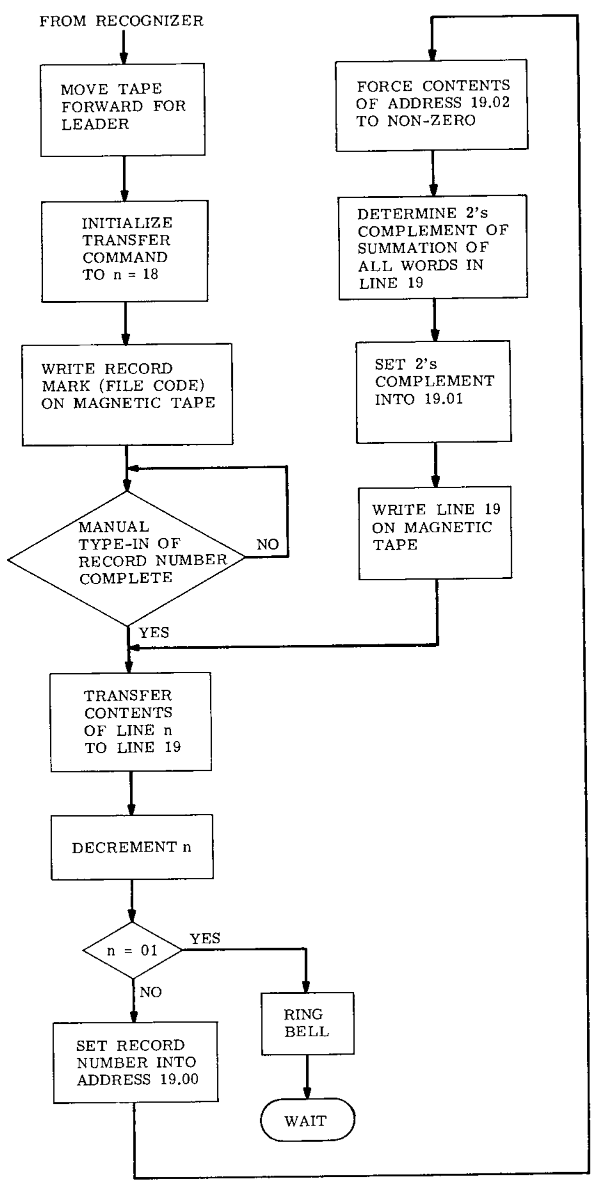
Since the commands for selecting lines and testing for completion of the loop are also on the drum, these commands are located for minimum access coding, requiring a very small part of the revolution for updating the address of line to be transferred. The result is a minimum interruption to a steady flow into line 19 and an essentially continuous display over the entire block of data. The program remains in the display loop until manually stopped by the operator.

Write on Library Tape (WOO) – This routine permits data stored in the computer memory to be recorded on the standard Bendix MTA-2 magnetic tape unit. Recorded with the data are a "record number " and "record mark." The term "record" is used to describe the block of information recorded on tape in contiguous sections corresponding to seventeen lines of data from the drum memory. The record number is typed in by the operator for use in the program and logged in a book for reference.

The tape write command records all data from line 19. Prior to the initiation of the write command, a computed value is inserted in an available word time of the line such that the summation of all words in the line will equal zero. This provides a convenient method for checking accuracy when the data is played back.

The flow chart (Fig. 11) indicates the general sequence of instructions in the program. Single operations preceding the repetitive loop to record from the seventeen lines reserved for data storage include moving tape forward an amount equal to at least one record for a blank leader between records, initial setting up of commands, and the writing of the file code on tape.

Fig. 10 - Visual monitor (VOO)



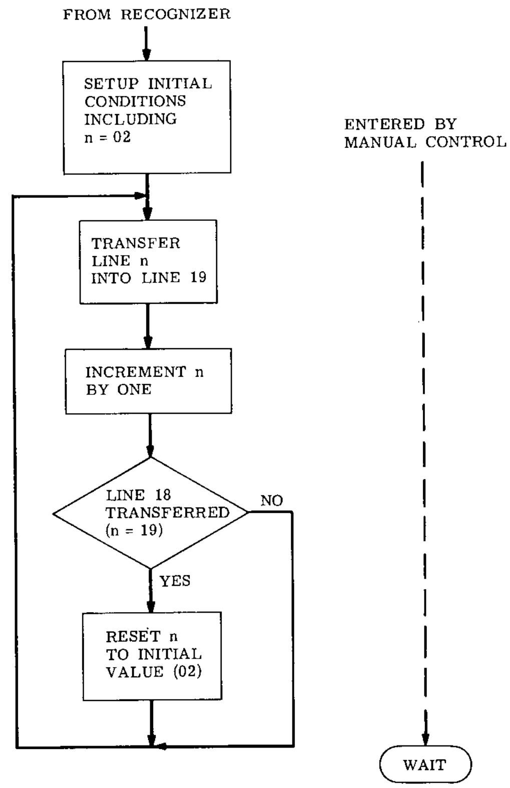


Fig. 11 - Write on library tape (WOO)

The program then accepts and stores the type-in by the operator of a record number. After completion of the type-in, line "n" (n is initially 18) is block transferred to line 19. A test for completion of the entire record is made on the decremented value of "n." When "n" has reached the value 01, seventeen lines have been recorded on tape and the program waits for intervention by the operator.

If the record has not been completed, the record number is placed into a location in line 19 and the contents of another location are made nonzero to prevent the possibility of four successive all zero words on the tape. If this were allowed, the read operation might experience difficulty through sensing what appeared to be blank tape for longer than an allowed interval.

A block command is used to compute the two's complement of the sum of all words now in line 19 and this value is set in another location in the line so that the total check sum, including this value, is zero. Line 19 is then written on magnetic tape.

The loop is entered with a new value of n and recording of separate lines continues in this way until all seventeen lines have been recorded.

Small gaps are automatically placed on the tape between each recorded line of data. However, the record number applies to all seventeen lines and the group is normally used as one unit even though an individual line (or selected line) could be read by a programmed counting procedure, if desired.

Search Data Tape (±XOO) – This routine allows the operator to locate a particular file on a data tape. It does so by searching for a file with the same check sum as that supplied to the program by the operator. Since the check sums of the files are not sequential numbers, but are random, the operator should position the tape so that a file with the known check sum will be read, preferable with a minimum of trials. The check sums are not recorded on the data tape and the program therefore must read each file to a line in memory and perform the summation in order to make the necessary comparison.

The flow chart (Fig. 12) outlines the general sequence of instructions. Some details of the read operation have been omitted because this part of the program is like the "read data tape" subroutine (±Unn) previously described, except each file is always read to line 02.

The program accepts and stores the typed-in check sum. The sign in the arithmetic register (AR) is then sensed to determine the desired direction of tape movement and one file of data is read into line 02. This data is summed and the result compared with the specified check sum. If the result is zero, the desired file has been located and the tape is now at a known position and the operator can use this fact as a reference for use of the standard "read data tape" subroutine. If the specified check sum was not found, the next file will be read and the process is repeated until the check sums agree.

Search Library Tape (YOO) – When records are written on the library tape, a record number is recorded with the data. These record numbers are arranged by the operator to be sequential. Based on these conditions, this routine can automatically locate a specific record on a library tape. It does so by reading the nearest record number and comparing it with the number supplied by the operator. The results indicate to the program in what direction and how many records away the desired record is located.

The sequence of operations (Fig. 13) is as follows: The desired record number is accepted and stored. Tape is moved in the reverse direction until a record number has been read (the record number is located at the beginning of each report). The first line of the record is now read into memory in the forward direction and the desired record number is subtracted from the record number just read from tape. If the difference is zero, the proper record has been located and control is returned to the recognizer program.

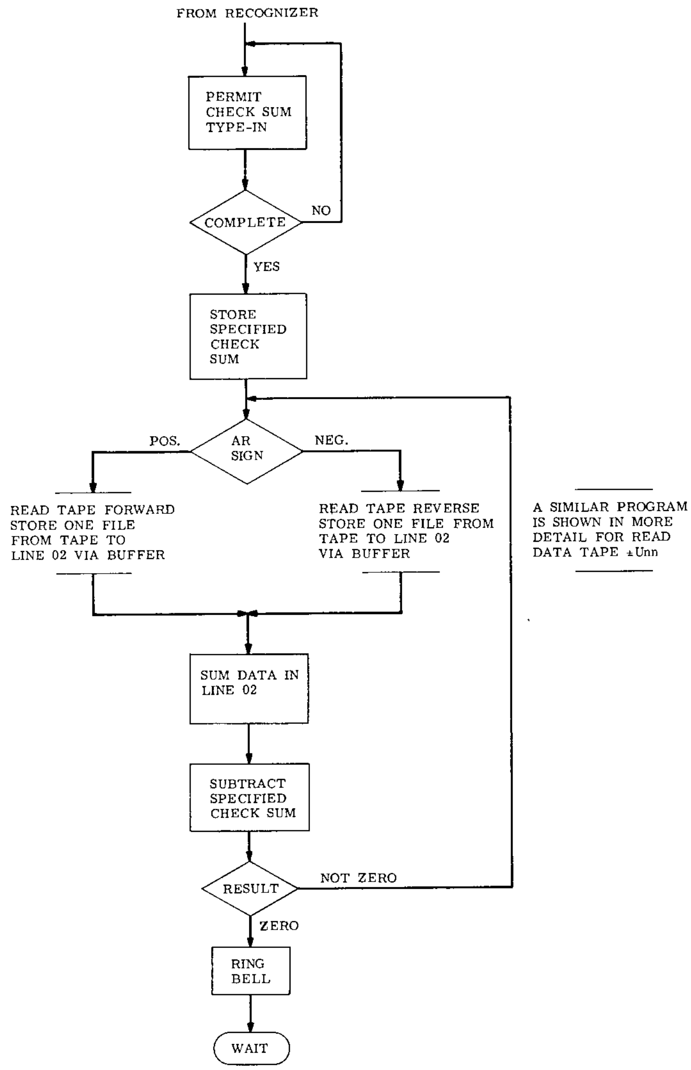


Fig. 12 - Search data tape (±XOO)

If the difference is nonzero, the sign is tested to determine in which direction the desired record is located. For a negative difference, tape is searched in the forward direction, passing a number of record marks equal to the absolute value of the difference. The tape is now in position to read forward the desired record. For a positive difference, it is necessary to add one to the difference and search in the reverse direction for proper positioning ready to read forward the chosen record.

After the tape is properly positioned, the record is read in to memory and the record number is checked to verify that the correct record was located. Unless there is a discrepancy, control is then returned to the recognizer program.

Read Library Tape (Z08 or Z17) - This routine is used for reading either eight or seventeen lines of a record into the computer. The choice of eight or seventeen lines was established by programming considerations for the correlation analysis of field data (8). During the reading process, a test for zero check sum for each line is made (the "write on

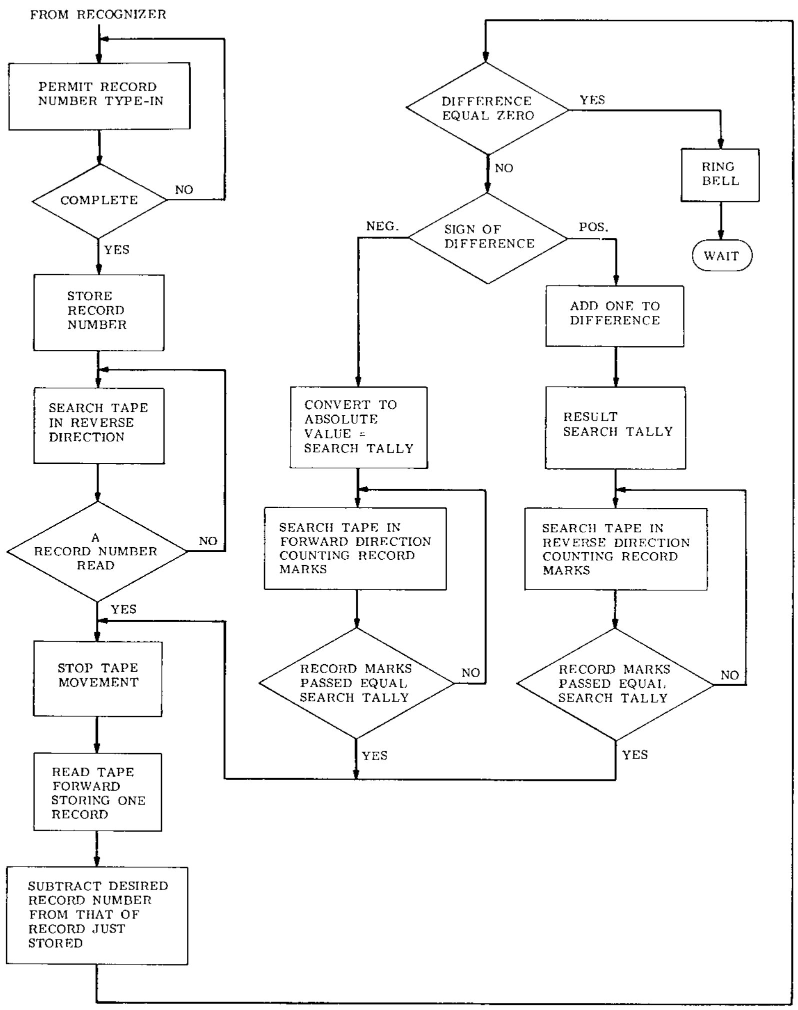


Fig. 13 - Search library tape (YOO)

on library tape" routine, previously described, forces the check sum to be zero) to verify accuracy of the data transfer. If the check sum of a line is not zero, repeated attempts are made to read the entire record.

The sequence of operations as outlined on the flow chart (Fig. 14) is as follows. The desired number of lines is first determined; an even-odd test is sufficient since the allowed options are only eight or seventeen. After a control number for the required amount of data has been set up, the tape is moved in the reverse direction until a file mark is read.

Tape is now read in the forward direction, one line of data is stored in line 19, and a block summation made. If this check sum is not zero, the program is restarted and the cycle repeated including the movement of tape back to the file mark and resetting of address selection controls to their initial values.

If the check sum is zero, data is transferred from line 19 to line "n" (n ranges from 18 down to 02). The valus of n is decremented by one and a test made to determine if the designated number of lines have been read and stored. Either the next line is read and the check-and-store cycle repeated, or control is returned to the recognizer.

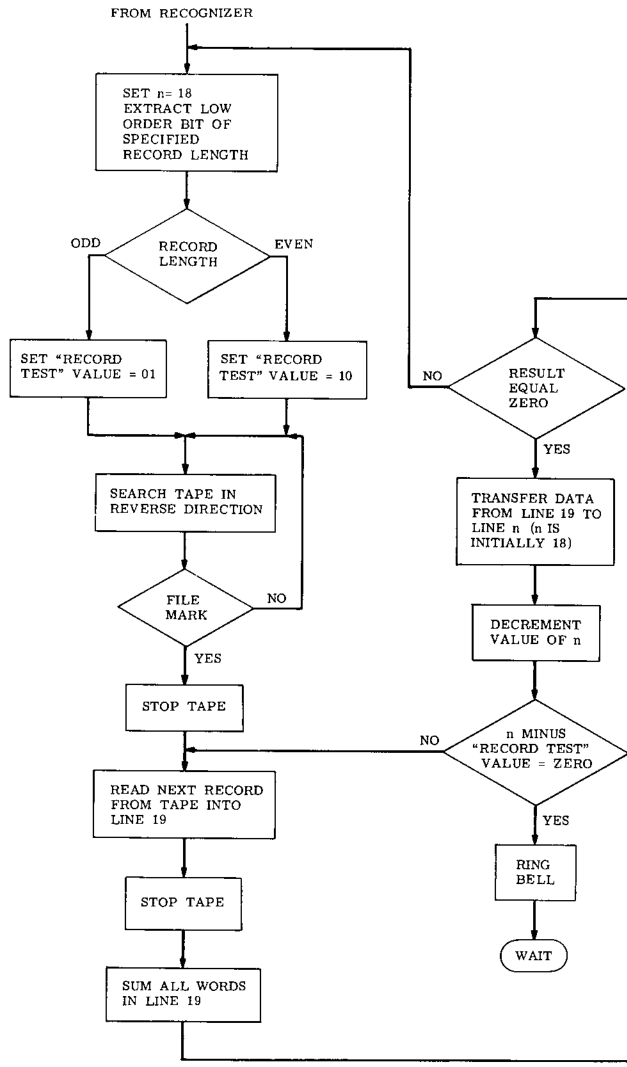


Fig. 14 - Read library tape (Z08 or Z17)

RESULTS

The data handling system has been in full operation by the Electronics Branch of the Sound Division since 1959 and was implemented by Mr. A.J. Rider (9). This system has been most valuable in facilitating transfer of field data to the computer for correlation studies and other statistical analysis. The use of the "Visual Monitor" (3) aids considerably in allowing for a visual inspection of the raw data prior to any computations.

The use of solid state logic in the hardware of the data handling system has given it long term reliability over its years of use with down time kept to a minimum without the use of periodic maintenance on the system. The hardware in this system may seem to be excessive on first inspection, but this is due primarily to the fact that data had to be transferred from a parallel digital tape recorder to a serial drum computer. In addition to this parallel-to-serial transfer, the system had to operate asynchronously and provisions had to be made for visual inspecting of data, checking each data word for parity errors, storing the data both in the computer and its auxiliary tape unit, and finally plotting out the calculated results on an x-y plotter.

CONCLUSIONS

The data handling system has made the taking of field data very straightforward and greatly simplified. Data taken in the field can be recorded continuously without making provisions for record gaps, and, in addition, multiplexing can be employed without regard to being compatible to a computer. The DHS will demultiplex and transfer the blocks of data that appear to be more desirable for processing.

The basic limitations of this system, by present-day standards, are the slow speed and limited storage of the computer. The principles developed in the DHS can be applied to a faster computer with a core memory, which will greatly simplify and reduce the amount of hardware and software. A newer computer with provisions for increasing its internal core storage will enable better correlation studies that require larger data storage to achieve more significant results. In the present system, a large proportion of the total internal storage is for programming rather than data storage.

REFERENCES

1. Peterson, H.L., and Finney, W.J., "Digital Signal Processing," Report of NRL Progress, p. 54, Apr. 1959

2. McCoy, C., Jr., and Peterson, H.L., "A Magnetic Digital Recording System for Field Use," NRL Report 6016, Nov. 15, 1963

3. Rider, A.J., "A Visual Monitor for the Bendix G-15D Digital Computer," NRL Memorandum Report 994, Aug. 20, 1959

4. Rider, A.J., and Peterson, H.L., "Digital Computer Monitor," Report of NRL Progress, pp. 54-55, Apr. 1959

5. Rider, A.J., "Automatic Graph Plotting from Serial-Type Digital Computer," NRL Memorandum Report 1009, May 1960

6. Finney, W.J., and Peterson, H.L., "Handling, Visual Analysis and Selection of Digital Data (U)," Proc. of Acoustical Signal Processing Conference, Office of Naval Research, July 26-27, 1960 (S)

7. Peterson, H.L., and Finney, W.J., "Selection and Analysis of Recorded Acoustic Data from the Sea," Automatic Control, 12, No. 1:48, 50, 52, Jan. 1960

8. Uliana, E.A., and Peterson, H.L., "Laboratory Handling and Analysis," Report of NRL Progress, pp. 38-39, Dec. 1962

9. Peterson, H.L., "Selection and Analysis of Recorded Data with the Bendix G-15D Computer," Bendix Users Exchange Conference, Palo Alto, Calif., Sept. 18, 1959