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Author : Jørgen Broge
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RC 3600 PERIPHERAL DEVICES
MTC 304 MAGNETIC TAPE SYSTEM
REFERENCE MANUAL

Keywords : NOVA Manual, Magnetic System
Abstract : This paper describes the logical structure of the Magnetic Tape System to be connected to the NOVA Computer

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1. MAIN CHARACTERISTICS

1.1 Description

The MTC 304 Magnetic Tape System enables transfer of data records consisting of a variable number of characters in both directions between the internal store of the NOVA computer and standard 9-track or 7-track recorded magnetic tape. The transfer is controlled via the Programmed I/O Channel and data are transferred via the Data Channel.

Recording and recovery can be performed by Phase Encoding (PE) and Non Return to Zero I (NRZI) encoding techniques as well. 7-track recording is always NRZI. The system may contain up to eight magnetic tape transports of mixed PE and NRZI types, but if both types are represented there can be only four of each. The tape transports are operated sequential in time. Figur 1.1 shows the hierarchal structure of the magnetic tape system.

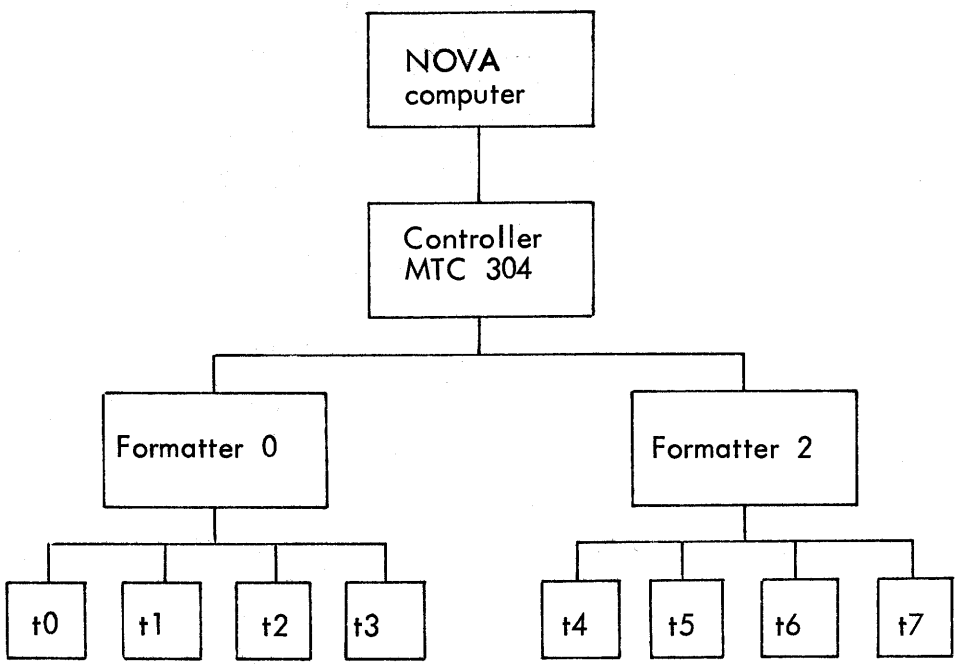


Fig. 1.1 The hierarchal structure of the magnetic tape system.
t: magnetic tape station (NRZI or PE)

1.2 Tape Specification

The magnetic tape used by the tape transport is compatible according to ISO, IBM, and ECMA standards (section 1.4).

The tape transports use 0.5 inch, 1.5 mil magnetic recording tapes which should be 3200 FLUX Reversions per Inch (FRPI) tested.

Up to 10.5 inches diameter standard reels containing up to 2450 feet (800 m) of tape can be applied, providing 23.5 million characters at 800 characters per Inch (CPI) or 47 million characters at 1600 CPI.

Figur 1.2 shows the physical tape lay-out. The BOT and EOT markers are reflective strips attached to the back of the tape. The tape is said to be positioned at the load point when the BOT marker is being sensed.

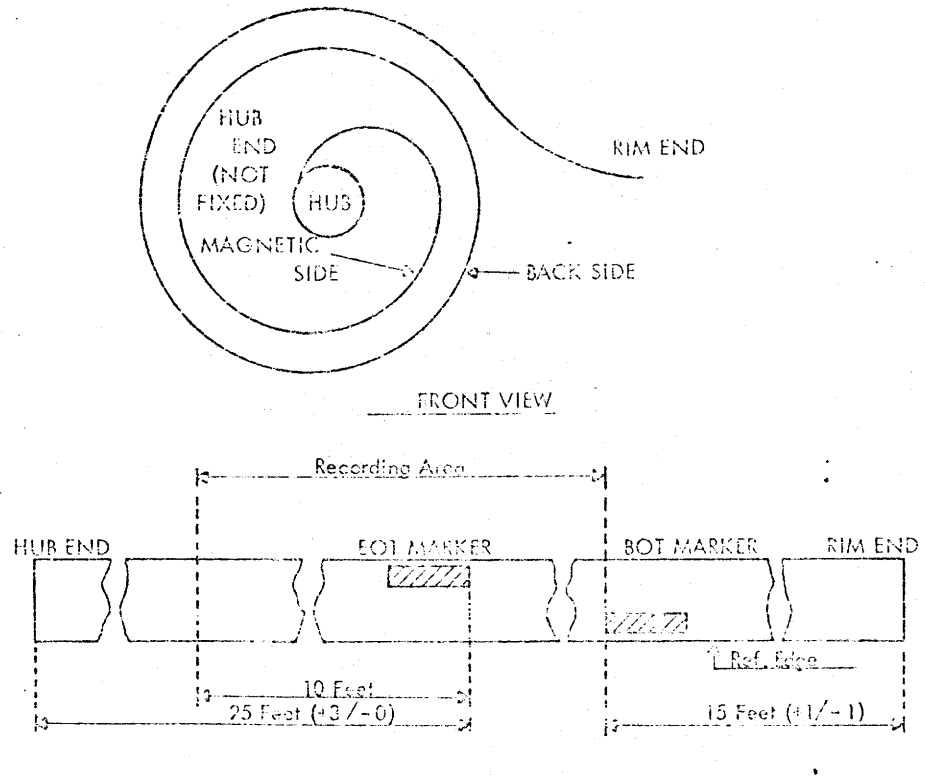


Fig. 1.2 Physical lay-out of magnetic tape, magnetic side down (back view) reflective BOT and EOT markers are 1.2 inches long and 0.2 inch wide.

1.3 Data Formats

On the tape data are recorded in records separated by inter record gaps. Each record may contain from 3 to 65534 characters, but note that the standard record lengths are 18 to 2048 characters.

1.3.1 9-Track Phase Encoded Data Format

Recording is performed in 9 tracks. The recording format is defined in fig. 1.3. Each character on the tape consists of 8 data bits numbered 0 to 7, plus the parity bit, P. When the character is interpreted as i binary number, bit 0 is the most significant bit. The character parity is odd.

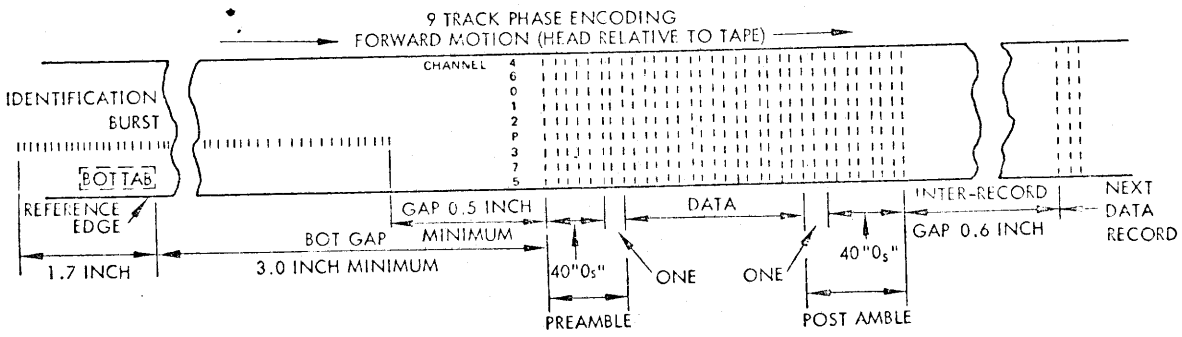


Fig. 1.3 9-Track PE Allocation, Spacing and Format

The data format used for 1600 CPI, Phase Encoded (PE) recording includes a preamble and a postamble to be attached to each data record. The preamble consists of 41 characters, of which 40 characters contain a zero-bit in all tracks and the last one contains a one-bit in all tracks. The postamble consists of 41 characters, of which the first one contains a one-bit in all tracks and the following 40 characters contain a zero-bit in all tracks.

The PE file mark is a special control record containing 64 to 256 flux reversals at 3200 FRPI in tracks 1, 2, 3, 4, 7, and 8. Tracks 3, 6, and 9 are DC-erased.

Generation and check of pre- and postambles are carried out automatically by the controller.

1.3.2 9-Track NRZI Encoded Data Format

Recording is performed in 9 tracks, and the recording format is defined in the figures: 1.4, 1.5, and 1.6. Each character on the tape consists of 8 data bits numbered 0 to 7, plus the parity bit. When the character is interpreted as a binary number, bit 0 is the most significant bit. The character parity is always odd.

The data format used for 9-track NRZI magnetic recording includes 2 check characters to be attached to each data record, the cyclic redundancy check character (CRCC), and the longitudinal redundancy check character (LRCC). The check characters are automatically generated according to ECMA-5 and USASI X3.2.-1967 standards. The cyclic redundancy check is not performed during read operation. The 9-track NRZI file mark is a special control record containing 1 character with one-bits in the traks 2, 3, and 8 (decimal value 19), followed by the LRCC.

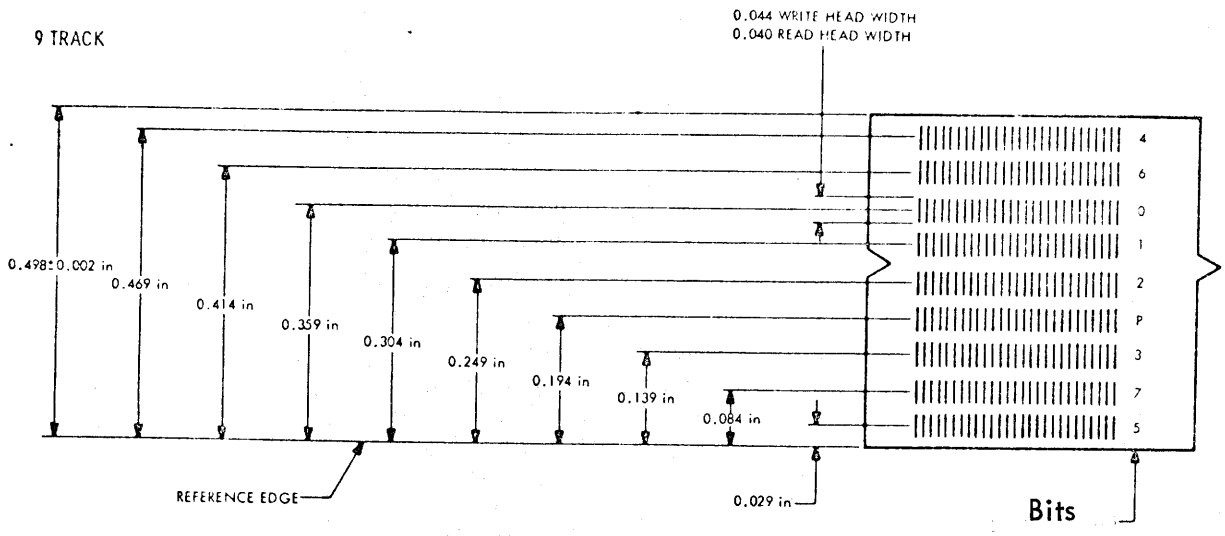


Fig. 1.4 9-Track NRZI, track allocation and spacing

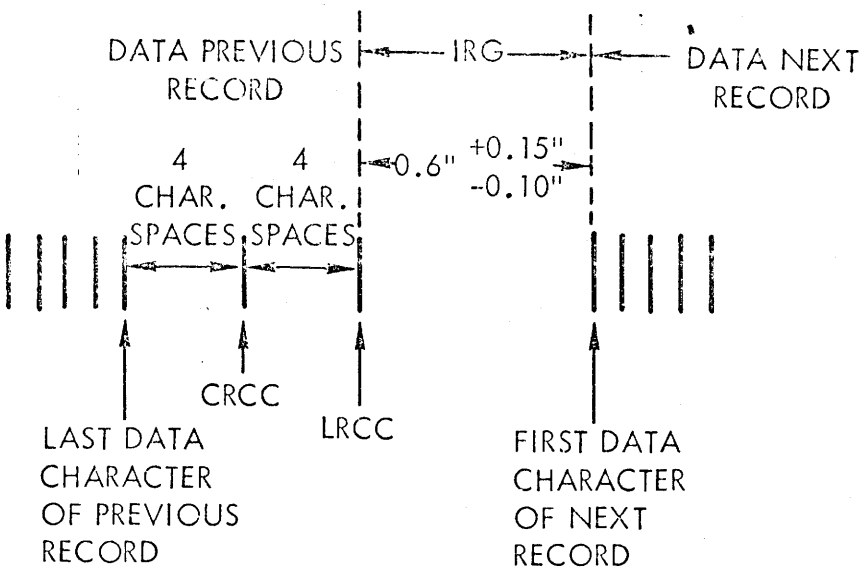


Fig. 1.5. 9-track NRZI, Inter Record Gap Format.

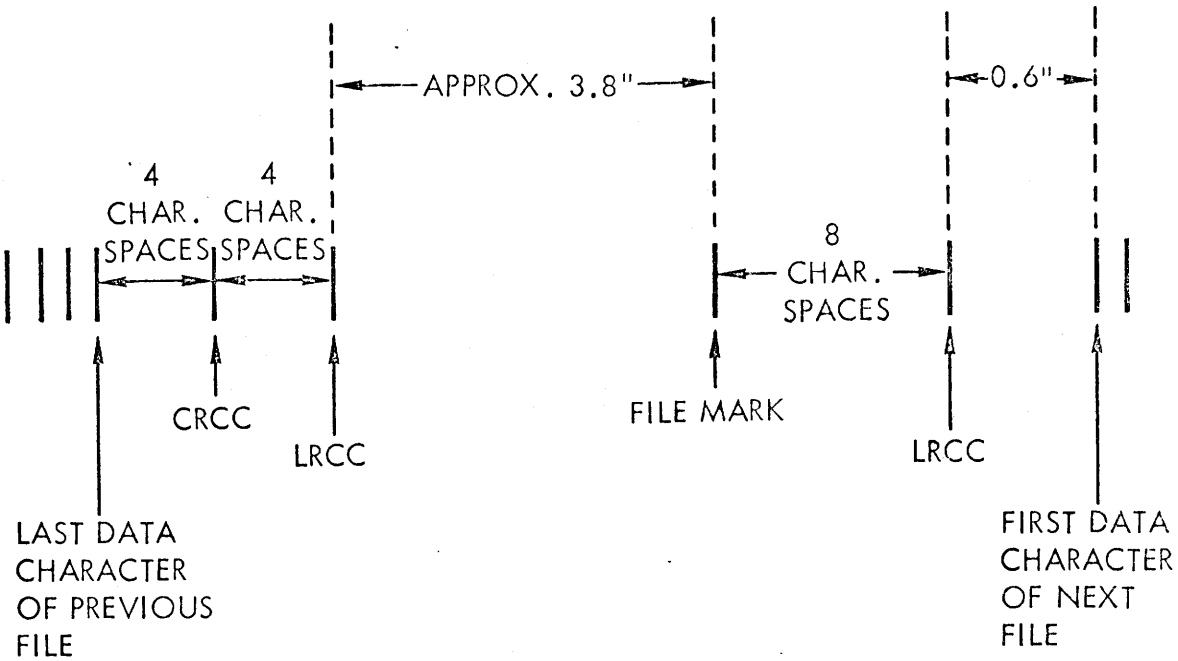


Fig. 1.6. 9-track NRZI, File Gap Format.

1.3.3 7-Track NRZI Encoded Data Format

The recording is performed in 7 tracks, and the recording format is defined in the figures: 1.7, 1.8, and 1.9. Each character on the tape consists of 6 data bits numbered 2 to 7, plus the parity bit. When the character is interpreted as a binary number, bit 2 is the most significant bit. The character parity can be selected odd or even under program control.

The 7-track format only includes one check character, the Longitudinal Redundancy Check Character (LRCC). The check information is automatically generated/ checked by the controller.

The 7-track NRZI file mark is a special control record containing one or more characters in even parity with the binary value 15. In the file mark generated by the system the record only contains one character.

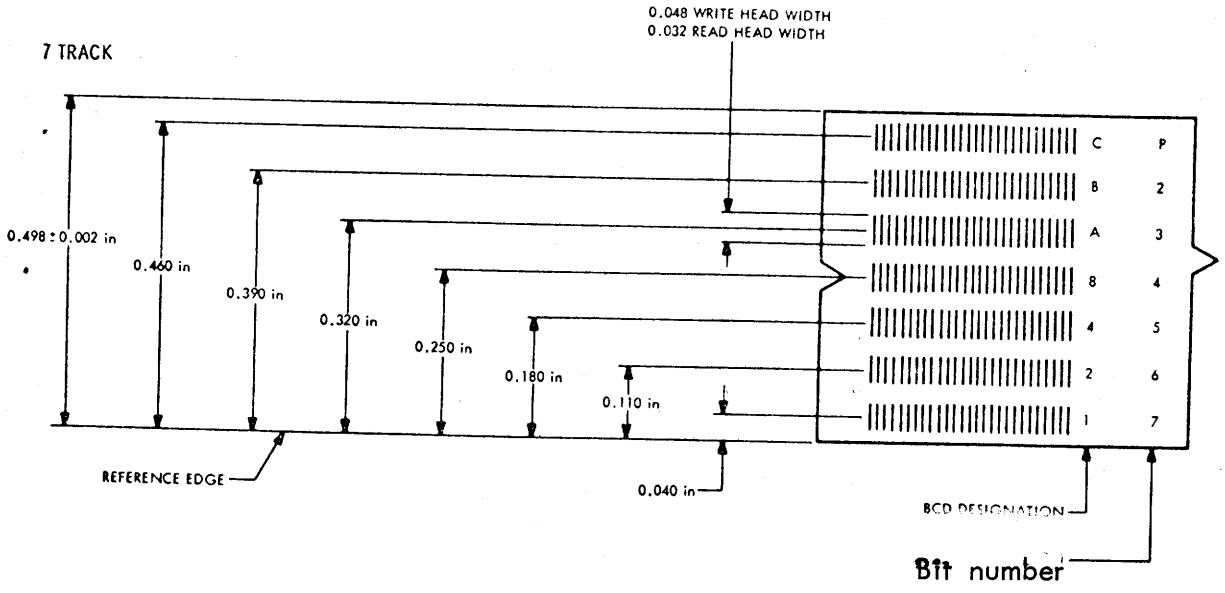


Fig. 1.7. 7-Track NRZI, Track Allocation and Spacing.

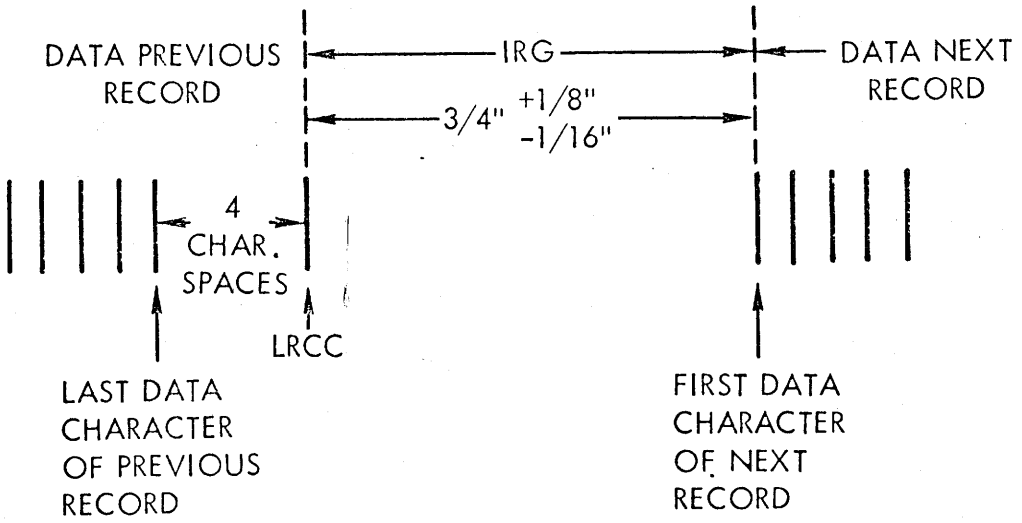


Fig. 1.8. 7-Track NRZI, Inter Record Gap Format.

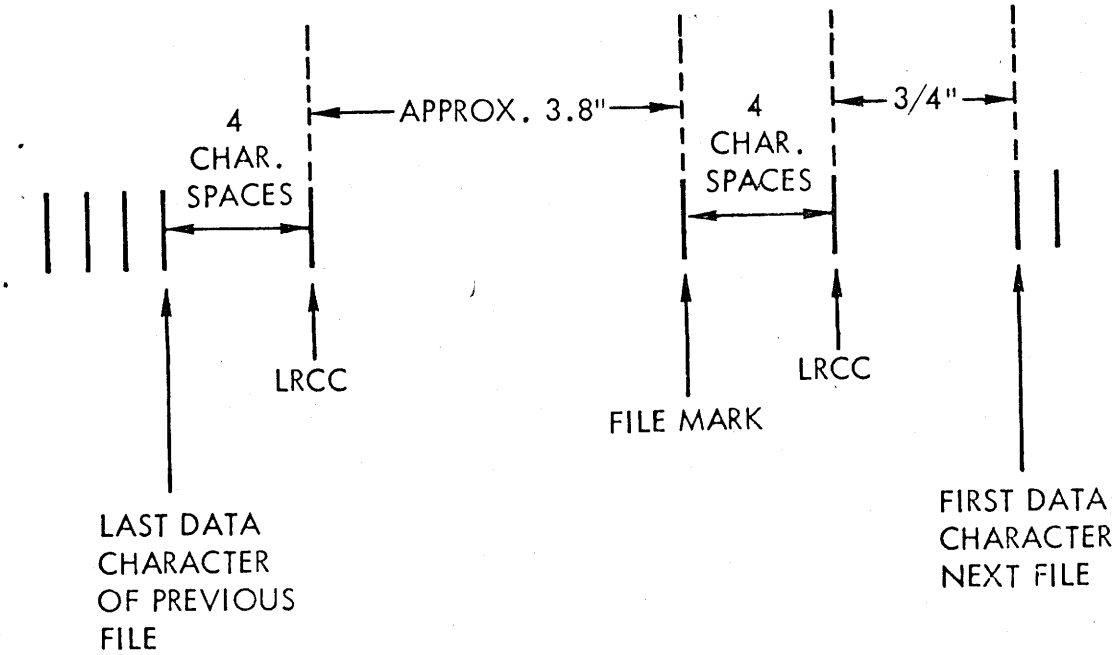


Fig. 1.9. 7-Track NRZI, File Gap Format.

1.3.4 Records and Data Words

Each NOVA data word is recorded as 2 consecutive characters on tape, except for the last word in each record which may be recorded as a trail of 1 or 2 characters.

Figure 1.10 shows relations between data words in the internal store and the characters on tape. All checking and formating except CRC-correction are performed by the tape system and imply no transfer of data to/from the internal store.

Buffer Start	B	c(1)	c(2)
	B + 1	c(3)	c(4)
	B + 2	c(5)	c(6)
		c(2n-3)	c(2n-2)
Buffer End	B+(n-1)	c(2n-1)	c(2n)

Fig. 1.10 Record lay-out in internal store buffer area.
Record length: n (words).
Character number within the block: c(x).

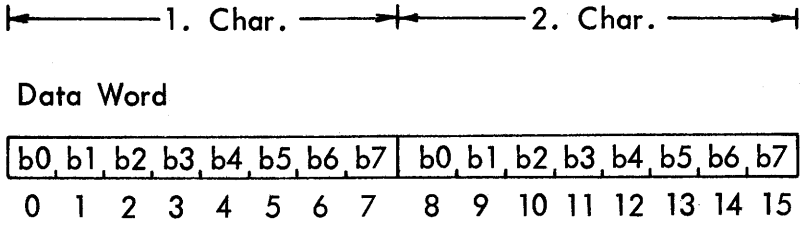


Fig. 1.11 Bit Allocation in Data Word

Fig. 1.11 shows the bit allocation in the data word.
In 7-track recording b0 and b1 is zero.

In Read Packed mode data are read from tape and transferred to the internal store as specified in figures 1.10 and 1.11.

In Read Unpacked mode each data word only contains one character. The spare bits are used for transfer of check information and the format of the data word is shown in fig. 1.12.

Data Word

E	C	0	0	0	0	0	P	b0	b1	b2	b3	b4	b5	b6	b7
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Fig. 1.12 Bit Allocation in Data Word in Read Unpacked Mode
E: Parity Error in Character
C: Check Character
P: Parity Bit

Buffer Start	B	c(1)
	B + 1	c(2)
	B + 2	c(3)
		⋮
Record End:	B+(n-1)	c(n)
	B+n	CRCC
Buffer End:	B+(n+1)	LRCC

Fig. 1.13 Read Unpacked Mode Record lay-out in internal store buffer area
B: Start Address
n: Block Length
c(x): Character no. x in the record
CRCC: Cyclic Redundancy Check Character
LRCC: Longitudinal Redundancy Check Character

Fig. 1.13 shows the format of the buffer area in the internal store in Read Unpacked mode. The CRCC is only transferred if the recording mode is 9-track NRZI and the binary value of the CRCC is different form zero. In PE-mode no check characters are transferred.

1.4 Applicable Documents

Additional information about magnetic tape and the NOVA computer can be obtained from the documents listed below.

1.4.1 Magnetic Tape

1. Standard ECMA-12 for Data Interchange on 9-track Magnetic Tape at 31.5 Rows per mm (800 rpi).
2. ISO Recommendation, Draft No. 1862, 9-track 800 RPI (32 RPmm) Magnetic Tape for Information Interchange.
3. United States of America Standard, Recorded Magnetic Tape for Information Interchange (800 CPI, NRZI), X 3.2-November 1967.
4. Proposed United States of America Standard, Recorded Magnetic Tape for Information Interchange (1600 CPI, Phase Encoded), X 3.2.1/400 November 1969.

1.4.2 NOVA Computer

1. System Reference Manual, NOVA SYSTEM LIBRARY, September 1970.

2. PERFORMANCE CHARACTERISTICS

2.1 The Tape Transport

Operating speed of the tape transport is 25 inches per second (IPS). Rewind time for 2400 feet of tape is approximately 3 minutes, and the start/stop time is approximately 15 milliseconds.

Data transfer rate within a block is 40k characters per second (CPS) for PE and 20 KCPS for NRZI or 20k words per second (WPS), and 10k WPS, respectively.

2.2 Operational Features

The tape system distinguishes two kinds of program initiated operations. The time consuming operations except rewinding is terminated by an interrupt while the immediate operations are executed within 3 micro-seconds and do not cause any interrupt.

The result of the last program initiated operation is stored in a status word available to the program when no operation is in progress. Under certain conditions it is impossible to execute an operation and then it is terminated immediately with the reason for the rejection available for the program in the status word.

Short-lived changes in status are buffered, and no changes in status can be lost if the program senses the status word after each operation.

Rewinding is not terminated by an interrupt because one or more of the tape transports (see fig. 1.1) can be rewinding during a data transfer to or from another transport.

2.2.1 Error Correction Features

The tape system includes single- and multi-track error detection and single-track error correction facilities.

During NRZI input the system supervises the transversal and the longitudinal parity. When operating with 9-track format a single track error can be corrected by the program without re-reading, because both data and check information can be transferred to the internal store in Read Unpacked mode (see 1.3.4)

During PE input the tape system supervises the preamble, the synchronization of each track, the transversal parity, and the postamble. If a single-track synchronization error is detected within the data block, the track is corrected by means of the redundancy provided by the known transversal parity. Multi-track synchronization errors within one block cannot be corrected. Note that correction of a single-track error by PE reading does not require any re-reading.

2.2.2 Load Point Erase Action

When a write operation is initiated at load point, a special action is included to ensure that 3 inches of tape between the BOT marker and the first block are either DC-erased or if it is a PE transport the PE identifier burst is recorded.

2.3 Check and Protection Features

The tape system provides read-after-write verification of the data transferred to the tape during output, and output is only possible if a write enable ring is present on the tape reel. Any attempt to write on a tape without write enable ring is rejected, i.e. the tape does not move and the operation is terminated immediately.

3. LOGIC SPECIFICATION

Program control of the tape system is provided through five of the IO transfer instructions. Busy and Done are controlled or sensed in IO instructions with device code 30*(octal), and interrupt disable is controlled by interrupt priority mask bit 5. The clear function (F=10) clears Busy and Done. Start (F=01) clears Done, sets Busy, and if the status situation allows it, the operation indicated by the contents of the command register is executed, else it is terminated immediately. The tape system terminates all program initiated operations by clearing Busy, and if it was a time consuming operation, Done is set. The IORST instruction clears the Busy and Done flags and all registers. An immediate command is terminated within 3 microseconds after the starting instruction.

Fig. 3.1 shows the data paths of the tape system.

* NOTE: A second magnetic tape system will have the device code 44 octal.

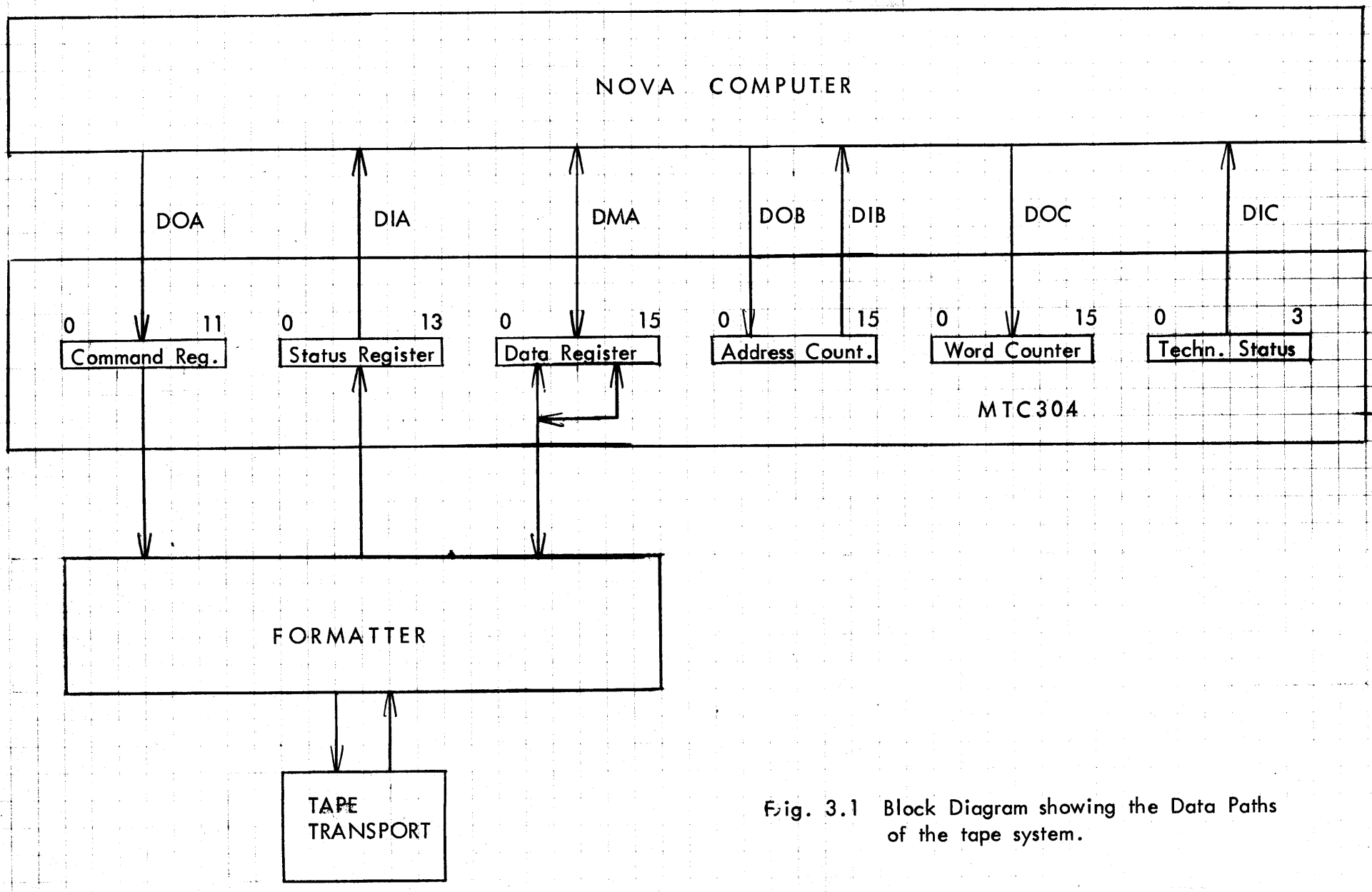
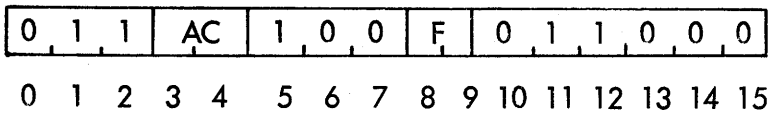


Fig. 3.1 Block Diagram showing the Data Paths of the tape system.

DOB - Instruction



Contents of AC

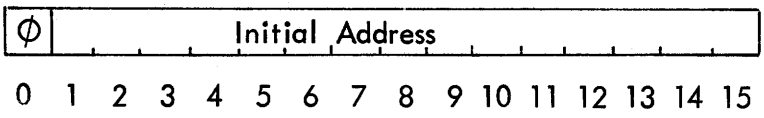


Fig. 3.2 The Data Out B instruction

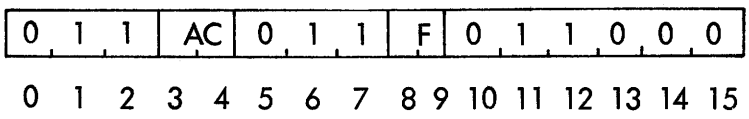
3.1 The Address Counter

The DOB instruction (see fig. 3.1 and 3.2) loads the contents of AC(1:15) into the Address Counter.

When a transfer operation is started, the first data word is transferred to or from the core store location specified by the contents of the Address Counter, and after each transfer the Address Counter is incremented by one. When a transfer operation is terminated, the contents of the Address Counter will be one greater than the address of the core store location to or from which the last data word was transferred.

During a Space operation the contents of the Address Counter is incremented with the number of characters spaced.

DIB - Instruction



Contents of AC

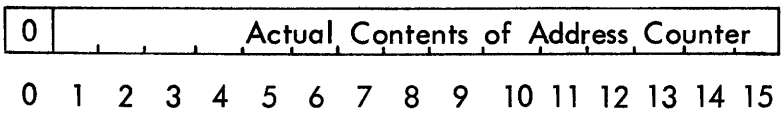


Fig. 3.3 The Data In B Instruction

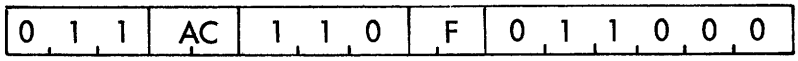
After a transfer or space operation the program can sense the contents of the Address Counter by means of a DIB instruction (see fig. 3.1 and 3.2) and thus determine the length of an unknown record.

The DIB instruction does not change the contents of the Address Counter.

3.2 The Word Counter

The DOC instruction (see fig. 3.1 and 3.4) loads the contents of AC (0:15) into the Word Counter. Before starting a transfer operation, the program must preset the Word Counter to the desired (negative) block length.

DOC - instruction



Contents of AC

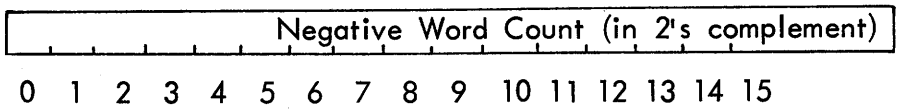


Fig. 3.4 The Data Out C instruction

The Word Counter is incremented after the transfer of each data word, and further transfer of data is prevented, if overflow occurs in the Word Counter.

3.3 The Command Register

The DOA instruction (see fig. 3.1 and 3.4) loads the contents of AC (5:15) into the Command Register.

The program starts a tape system operation by executing an IO instruction with modification S (F=10, sets Busy and clears Done), and the actual contents of the Command Register then specifies the type of operation. If the start instruction is a DOAS, then the Command Register is set before the operation is executed.

DOA - Instruction

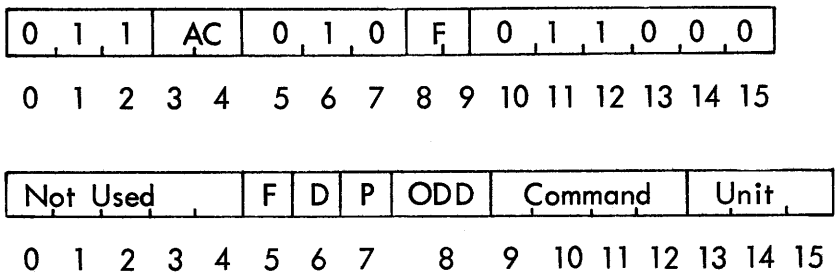


Fig. 3.5 The Data Out A instruction

The unit field, bits (13:15), in the command specifies the number (0-7) of the tape transport on which the command shall operate, (Bit 13 specifies the formatter). The Command field, bits (9:12), specifies the command to be executed. The commands are listed in fig. 3.6.

Command code	Mnemonic
0	Read packed
1	Write
2	Space Forward
3	Space Reverse
4	Write End of File
5	Erase
6	Read unpacked
7	Rewind
8	Off-line
9-15	No operation

Fig. 3.6 Command Table

A one in the ODD field, bit (8), specifies that an odd number of characters shall be output in a write operation, i.e. the last character to be output from the buffer shown in fig. 1.10 is c (2n-1). If the odd field is zero, all characters in the specified buffer are output.

The P field only apply to 7-track transports. A one in this field specifies even parity while a one in the D field selects the lower of two possible densities.

If the command is a Space command and there is a one in the F field then the tape will be spaced to the next file mark.

3.3.1 The Read Packed Command

The tape system will always terminate the execution of this command by setting Done. A read packed command is rejected if the status of the addressed tape transport is: Off-line, or Rewinding, and in this case updating of the status register is the only effect.

During normal read operation the tape system reads a single record from tape and transfers the data via the Data Channel to the locations specified by the Address Counter (see fig. 1.10 and 1.11) until the End of Record gap is encountered or the word counter overflows, whichever occurs first.

If the record contains an odd number of characters, the final one is sent to the buffer area in a separate word left justified. If the Data Late situation occurs during a read packed operation, the Data Late status will be set, but the operation continues until the record or the buffer ends.

After a read packed operation the contents of the Address Counter will always be one greater than the address of the core store location to which the last word was transferred, and the tape will be positioned in the Inter Record gap.

3.3.2 The Write Command

The tape system will always terminate the execution of this command by setting Done. A write command is rejected if the status of the addressed tape transport is: Off-line, Rewinding, or Write Lock, and in this case updating of the status register is the only effect.

When a write operation is started, the tape system will transfer characters from the specified buffer area (see fig. 1.10 and 1.11) until the end of buffer is reached. At this moment the system will generate the proper check and formating characters and the write operation is terminated.

3.3.3 The Space Forward Command

The tape system will always terminate the execution of this command by setting Done. A space forward command is rejected if the status of the addressed tape transport is: Off-line, or Rewinding, and in this case updating of the status register is the only effect.

If the F field is zero the tape is spaced forward one record, else it is spaced forward one file (positioned immediately after the next file mark).

3.3.4 The Space Reverse Command

The tape system always terminates the execution of this command by setting Done. The command is rejected if the status of the addressed tape transport is: Off-line, Rewinding, or Begin of Tape, and in this case updating of the status register is the only effect.

If the F field is zero then the tape is spaced in reverse direction one record, else it is spaced reverse one file (positioned immediately before the file mark).

If the Begin of Tape marker is encountered then the operation is terminated and the Illegal status is set.

3.3.5 The Write End of File Command

The tape system always terminates the execution of this command by setting Done and the conditions for rejection are as for the write command.

During write end of file operation a special file mark record, see sections 1.2.1, 1.3.2, and 1.3.3, will be written on the tape. The system automatically distinguishes between NRZI and PE file marks.

3.3.6 The Erase Command

The tape system always terminates the execution of this command by setting Done, and the conditions for rejection are as for the write command. The effect of the erase operation is that approximately 3.75 inches of tape are erased in the forward direction.

3.3.7 The Read Unpacked Command

The tape system will always terminate the execution of this command by setting Done. A read unpacked command is rejected if the status of the addressed tape transport is: Off-line, or Rewinding, and in this case updating of the status register is the only effect.

During normal read unpacked operation the tape system reads a single record from tape and transfers the data via the Data Channel to the locations specified by the Address Counter (see fig. 1.12 and 1.13) until the End of Record gap is encountered or the word counter overflows, whichever occurs first.

If the Data Late situation occurs during a read operation, the Data Late status will be set, but the operation continues until the record or the buffer ends.

After a read operation the contents of the Address Counter will always be one greater than the address of the core store location to which the last character was transferred, and the tape will be positioned in the Inter Record gap.

3.3.8 The Rewind Command

The tape system does not terminate the execution of this command by setting Done, and the conditions for rejection are as for the read command.

During rewind operation the addressed transport rewinds the tape at high speed onto the supply reel and stops at load-point (BOT marker). The Busy flag is not set during rewind operation, but the Rewind status bit will be set if the program executes a start instruction with the contents of the Unit field addressing the rewinding transport.

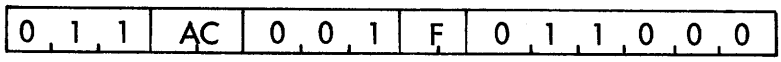
3.3.9 The No Operation Command

This is an immediate command and Done is not set. The command is never rejected and the only effect is updating of the status register.

3.4 The Status Register

The DIA instruction (see fig. 3.1 and 3.7) reads the result of the previous operation into the specified accumulator. The status bits are listed in fig. 3.8.

DIA - Instruction



Contents of AC

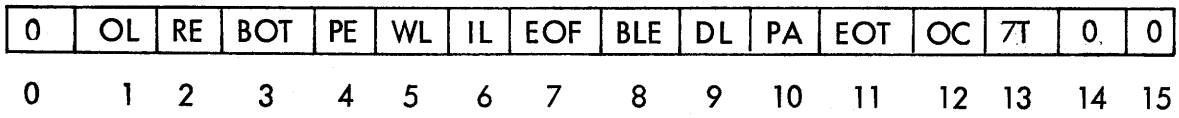


Fig. 3.7 The Data In A instruction

Bit No.	Mnemonic
0	0
1	Off-line
2	Rewinding
3	Begin of Tape (BOT)
4	PE
5	Write Lock
6	Illegal
7	End of File (EOF)
8	Block Length Error
9	Data Late
10	Parity
11	End of Tape (EOT)
12	Odd Character
13	7-track
14	0
15	0

Fig. 3.8 Status Bit Allocations

The status bits are flag signals and the mnemonics refer to the active onestate. In the following the meaning of each status bit is explained in detail.

3.4.1 Off-Line, Bit (1)

Indicates that the addressed transport is or has been in off-line mode. If a transport is in this mode, it can only revert to on-line mode by operator intervention, and in order to detect the mode shift the program must at regular intervals examine the off-line status bit after having executed a No Operation command. When a transport reverts to on-line mode, the tape will automatically be rewinded before the program can operate the transport.

3.4.2 Rewinding, Bit (2)

Indicates that the addressed transport was rewinding.

3.4.3 Begin of Tape. Bit (3)

Indicates that the tape on the addressed transport was at load point.

3.4.4 PE, Bit (4)

Indicates that the addressed transport was of the type operating with phase encoded recording.

3.4.5 Write Lock, Bit (5)

Indicates that a tape without write enable ring was mounted on the addressed transport.

3.4.6 Illegal, Bit (6)

This bit is set after rejection of a command if any of the following conditions holds:

1. The command was Write, Erase, or Write End of File, and Write Lock was set.
2. The command was Space Reverse, and the Begin of Tape markes was sensed.

3.4.7 End of File, Bit (7)

Indicates that a file mark (see sections 1.3.2 and 1.3.3) has been detected during the execution of the previous command. Note that this bit will be set after the execution of a Write End of File command and after a Space command if the spaced record was an End of File Mark.

3.4.8 Block Length Error, Bit (8)

This bit can only be set after a Read operation, and it indicates that the number of character positions in the specified buffer was smaller than the number of characters in the record which has been read.

3.4.9 Data Late, Bit (9)

Indicates that the Data Channel has failed to respond in time to a request for access during the previous operation.

3.4.10 Parity, Bit (10)

Indicates that a prity error has been detected during the previous operation.

Note that 7-track file marks causes the Parity status to be set. During space operation the Parity status can be utilized to detect noise records.

3.4.11 End of Tape, Bit (11)

Indicates that the End of Tape marker has been sensed during the previous operation.

3.4.12 Odd Character, Bit (12)

This bit can only be set after a Read or a Write operation, and it indicates that the record contained an odd number of characters, see section 3.3.1.

3.4.13 7-Track, Bit (13)

Indicates that the addressed unit was a 7-track transport.

3.5 The Technical Status Register

The DIC instruction (see fig. 3.1 and 3.9) reads the present value of some status signals into the addressed accumulator. This feature is intended as an aid in fault finding and maintenance.

DIC - instruction

0	1	1	AC			1	0	1	F	0	1	1	0	0	0
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Contents of AC

0	0	0	0	0	0	0	0	0	0	0	0	HE	CE	DB	1.C
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Fig. 3.9 The Data In C instruction

Bits (0:11) are zero. Bit (12) is a buffered status indicating that an uncorrectable read error has been detected during the operation.

Bit (13) is a buffered status indicating that an read error has been corrected. It can only be set if the addressed unit was a PE transport.

Bit (14) is the sampled value of a signal named Data Busy. It is true when data are actually read from the tape.

Bit (15) is a buffered status indicating that at least one character has been read.

4. OPERATOR's CONTROL PANEL

The operator can interfere with the tape system by means of a control panel on each tape transport. The indicators on the panel are active when main power is switched on while most of the pushbuttons are active in off-line mode only.

4.1 Power

The power button is an alternate action switch/indicator which connects main power to the transport. The indicator is lit when power is switched on, and after power start-up the transport is in reset mode.

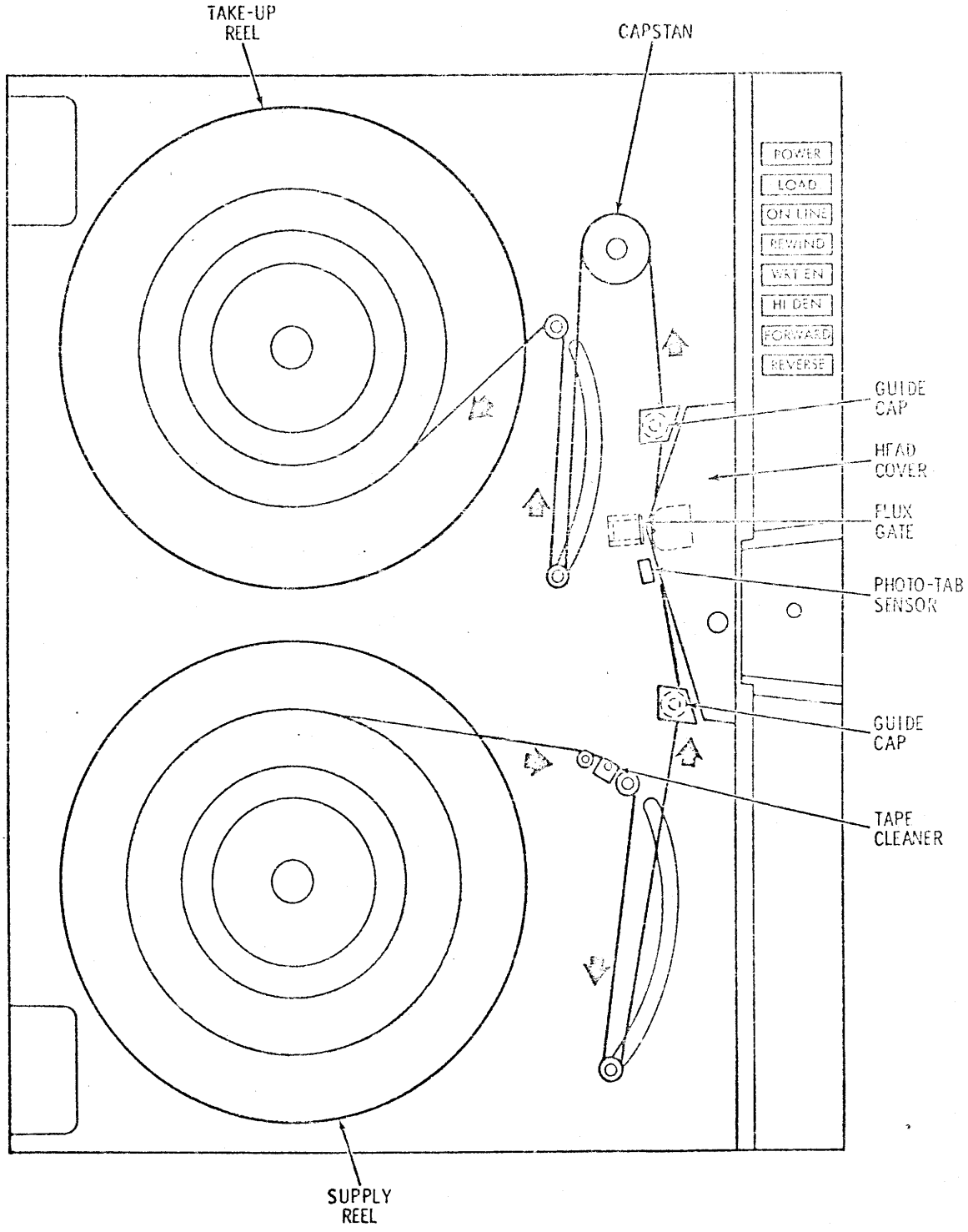


Fig. 4.1. Exhibits the front of a tape transport with the operator's control panel, tape reels, and tape path.

4.2 Load

The load button is a momentary action switch/indicator. Depressing and releasing the button for the first time after power is switched on energizes the servo system, and the tape will now be tensioned.

Depressing and releasing of the button for the second time causes the tape to move to and stop at the Load Point, and the transport is now ready to operate. The indicator is lit while the tape is at Load Point. The Load button is disabled after the first load or rewind operation and can only be re-enabled after loss of tape tension.

4.3 Rewind

The Rewind button is a momentary action switch/indicator which is enabled only in the off-line mode. Depressing and releasing the button cause the tape to rewind to Load Point at high speed. If the Rewind button is activated when the tape is at Load Point, the tape rewinds off the take-up reel and tape tension is lost.

The indicator is lit throughout any rewind operation.

4.4 On-line

The On-Line button is a momentary action switch/indicator which is enabled after an initial load or rewind sequence has been initiated.

The indicator is lit when the transport is in on-line mode, and the transport is switched to on-line mode if the button is activated in off-line mode. The transport will revert to off-line mode if

1. the On-line button is activated a second time,
2. the program executes an off-line command,
3. tape tension is lost.

4.5 Wrt en

This is an indicator which is lit when power is on and a reel of tape with a Write Enable ring installed is mounted on the transport.

4.6 Hi den

On 7-track transports this button selects one of two possible densities.

4.7 Forward

The forward button is an alternate action switch/indicator which is enabled only in off-line mode.

When the button is depressed, the indicator lights and the tape moves forward at 25 ips. When the button is depressed again (released), the tape stops and the indicator extinguishes.

If the End of Tape marker is encountered while moving forward, the tape stops but the indicator will remain lit.

4.8 Reverse

The reverse button is an alternate action switch/indicator which is enabled only in off-line mode.

When the button is depressed, the indicator lights and the tape moves backward at 25 ips. When the button is depressed again (released), the tape stops and the indicator extinguishes.

If the Begin of Tape marker is encountered while moving backward, the tape stops but the indicator will remain lit.