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TX-0 MEMORANDUM M-5001-17

A PROPOSED TAPE SYSTEM FOR THE TX-0

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This memo describes the proposed magnetic tape installation for the TX-0 and gives the present thoughts on computer instructions which will control it. It is planned to allow for expansion of the system to include as many as three separate tape drives under control of a stored program. First, the general characteristics and recording scheme of the commercial units being considered will be described. The proposed set of computer instructions for controlling the system will be presented along with some programming examples.

The Tape Units and the Recording System

The proposed system will use either the Ampex Model FR-400 or the Potter Model 906 tape handling mechanism. The information will be placed in a form compatible for use with the IBM 727 tape system, used on the 704, 709 or 7090. The reading and writing tape speeds will be 75 inches per second, and information will be stored on 7 parallel tracks across 1/2" tape. One bit from each track constitutes a character which is read into or written from the Live Register of TX-0. Two hundred characters are stored on each inch of tape, so that 15,000 characters may be transmitted per second. Information may be read or written only while the tape is moving the forward direction.

The system records information by saturating the tape in either the position or negative direction as shown in Fig. 1. The direction of tape magnetization is reversed each time a 1 is recorded. This is known as a non-return to zero (NRZ) system of recording. The flux reversals are transferred into pulses at the output of the read amplifiers where a pulse represents a 1, and no pulse a 0.

The IBM System of Recording

The IBM 727 tape units operate to detect a flux change, as previously described. There are 7 tracks recorded in a line across the tape. Six of the tracks transmit information, and the seventh track contains a parity check bit. The seven channels of the recorded information are added together to form a tim-

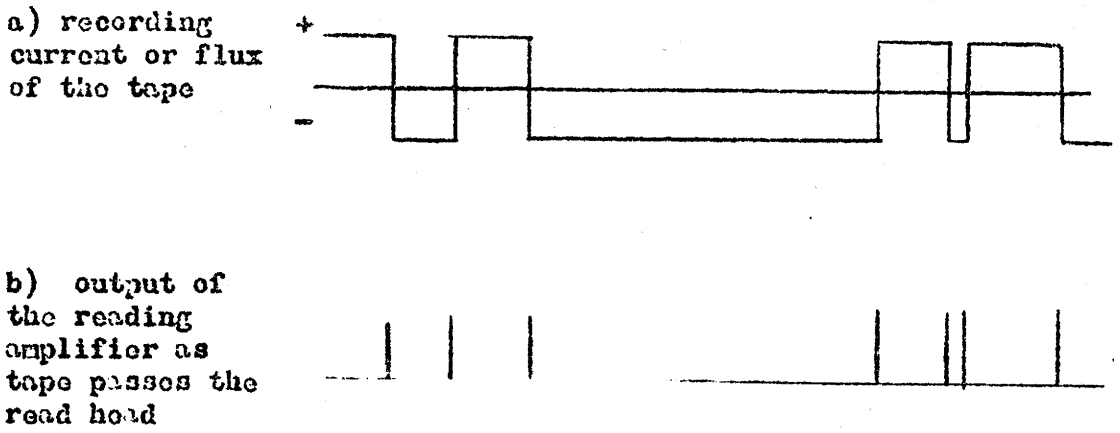


Figure 1

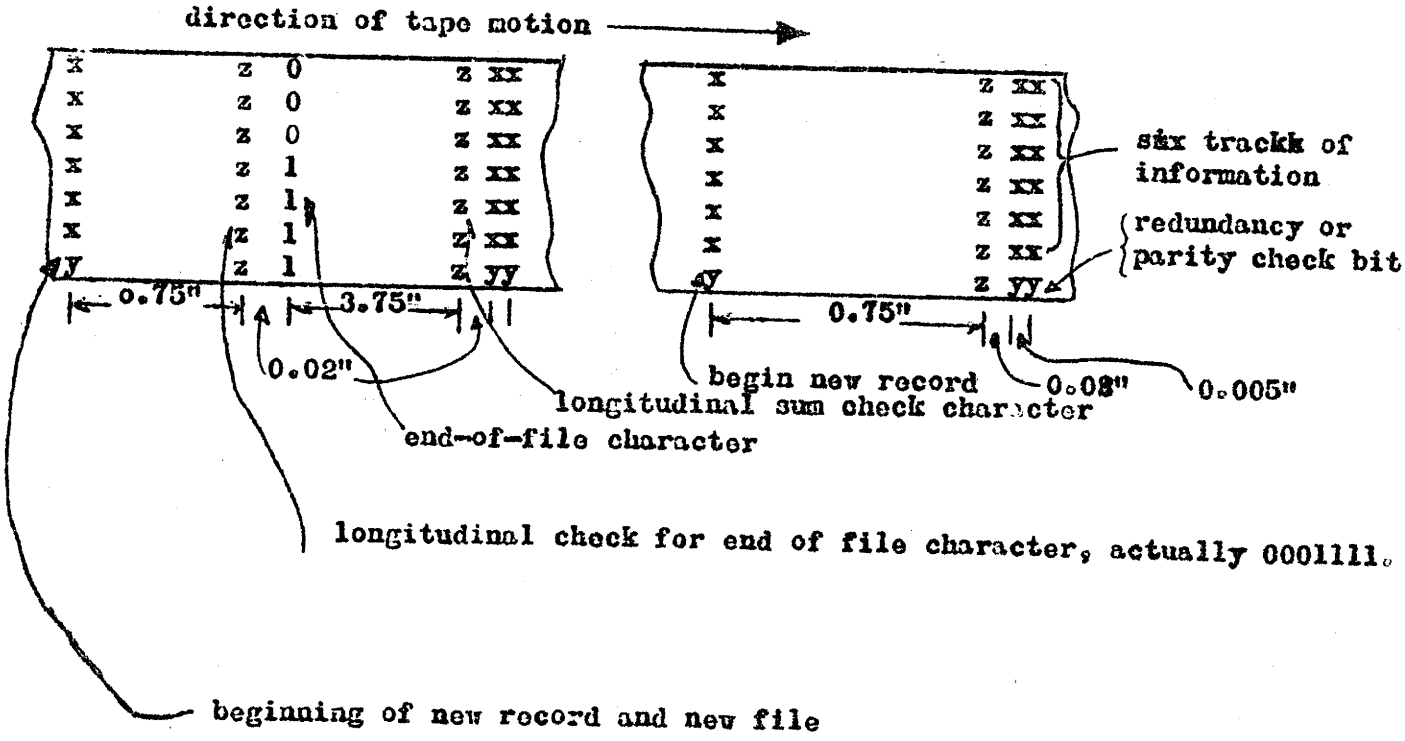
ing pulse which signifies when the seven channels of the line are to be read. Thus spaces may be detected by not writing in any of the seven channels. This system detects spaces either as an end-of-record, or an end-of-file. The track layout is shown in Fig. 2.

In addition to the checking bit of the six tracks, a longitudinal check is written at the end of a record, or file. This 7-bit character is the parity check of each track from the beginning of the record or file. This is an <u>even</u> check, i.e., the bit written forms an <u>even</u> number of 1's for the particular track.

The IBM 727 uses two modes of recording. The binary mode is for normal data recording, and the binary coded decimal (BCD) form is used to make recordings for use with peripheral equipment.

<u>The Binary Mode</u>

Six 6-bit words are placed on the tape to form a 704 word. The six words are placed such that the first 6 bits of the word (the least significant bits) appear first on the tape, followed by the second least significant bits, and finally the six most significant bits of the number. In this <u>binary mode</u>, the redundancy or parity bit is adjusted such that an <u>odd</u> number of bits appear



3.75" is end-of-file gap
0.75" is end-of-record gap
0.02" is space between longitudinal check and last character of last word written on tape
0.005" is spacing between characters on tape

Figure 2

across the tape in the seven channels of the recorded information.

The Binary Coded Decimal (BCD) Mode

This mode is only similar to the binary mode in that six, 6-bit words of a 704 word are placed on the tape. The words placed on the tape from a 704 word are first permuted for recording, and are also permuted when being read by the calculator. Only the peripheral equipment uses the altered form. In the BCD mode, not all of the 64 possible 6-bit characters are used. The parity or redundancy check bit is adjusted such that an even number of ones appears across the tape in the seven channels. Because the character 000000 would have a parity bit of 0, this would appear on tape as a space, and as such is not a legal character on the tape. Hence it is not used in the BCD mode. Table 1 shows how the various BCD characters are altered on the tape.

Character	In Store	On Tape	Character	In Store	On Tape
0	00 0000	00 1010	↔	10 0000	10 0000
1	00 0001	00 0001	J	10 0001	10 0001
2	00 0010	00 0010	K	10 0010	10 0010
3	00 0011	00 0011	L	10 0011	10 0011
4	00 0100	00 0100	M	10 0100	10 0100
5	00 0101	00 0101	N	10 0101	10 0101
6	00 0110	00 0110	O	10 0110	10 0110
7	00 0111	00 0111	P	10 0111	10 0111
8	00 1000	00 1000	Q	10 1000	10 1000
9	00 1001	00 1001	R	10 1001	10 1001
#	00 1011	00 1011	$\overline{0}$	10 1010	10 1010
@	00 1100	00 1100	$	10 1011	10 1011
&	01 0000	11 0000	*	10 1100	10 1100
A	01 0001	11 0001	Blank	11 0000	01 0000
B	01 0010	11 0010	/	11 0001	01 0001
C	01 0011	11 0011	S	11 0010	01 0010
D	01 0100	11 0100	T	11 0011	01 0011
E	01 0101	11 0101	U	11 0100	01 0100
F	01 0110	11 0110	V	11 0101	01 0101
G	01 0111	11 0111	W	11 0110	01 0110
H	01 1000	11 1000	X	11 0111	01 0111
I	01 1001	11 1001	Y	11 1000	01 1000
0	01 1010	11 1010	Z	11 1001	01 1001
.	01 1011	11 1011	‡	11 1010	01 1010
¤	01 1100	11 1100	,	11 1011	01 1011
			%	11 1100	01 1100

TABLE I

TX-0 Compatibility with the 704 Tape System

With the present MIT installation of the 704, it seems both desirable and necessary to be able to transfer binary data via magnetic tape between the TX-0 and the IBM 704. It also would seem desirable to be able to prepare tapes in the BCD mode used by IBM so that TX-0 magnetic tape output could also be used on the off line printer or for converting to IBM cards with the Computation Center off line equipment. A switch on the tape unit would probably be provided to accomplish BCD recording.

IBM compatibility places the following restrictions on the TX-0 tape system:

1. Parity or Redundancy Check Bit - The seventh track of a tape record would have to contain the parity check of the other six channels across the tape.
2. End-of-Record Check (EOR) - A longitudinal check sum must be written 0.02 inches behind the last character of a record on tape.
3. Bit Packing Density - Two hundred characters (a character is composed of the seven lateral bits) would be written on each linear inch of tape.
4. Indication of Load Point - A reflective strip would have to be added to the tape to indicate the load point for the tape.
5. Correct spacing for the End-of-Record gap - 0.75 inch gap of blank tape must be written for the EOR.

The proposals given below will satisfy these requirements.

Tentative Programming Information for the TX-0 Magnetic Tape System

The following group of orders will be provided to select one of three tape units and specify the operating mode. Here n is the unit number, n = 0, 1, or 2.

Magnetic Tape Select Orders

WRS n - Binary information is to be written from the LR in the forward direction using unit n, and the tape is set in motion with the "write" amplifiers recording positive flux.

RDS n - Binary information previously written is to be read into the LR from unit n, while the tape is moving forward.

BST n - The tape of unit n is backspaced to the beginning of the previous record. If the heads of the tape unit are at the beginning

of the tape, the order has no effect.

RWD n - Tape unit n is rewound until the tape is at the load point, or beginning.

RIM - Initiates transfer of information in the read-in mode from tape unit 0.

A select order will normally be executed in 12μs. However, if a previous order is active, the new select will be delayed until the former is complete.

The rewind select order, RWD n, will initiate rewind of the indicated unit and will be completed in a few milliseconds. However, the tape unit being rewound is unavailable to the program until the load point (or start of the tape) is reached. A select order to an unavailable unit is held up until the unit becomes available. A unit is also unavailable if the power is off, a tape is not properly loaded onto the mechanism, ~~or the door to the mechanism is open.~~

Tape Format

A TX-0 word is written in the format of Fig. 3.

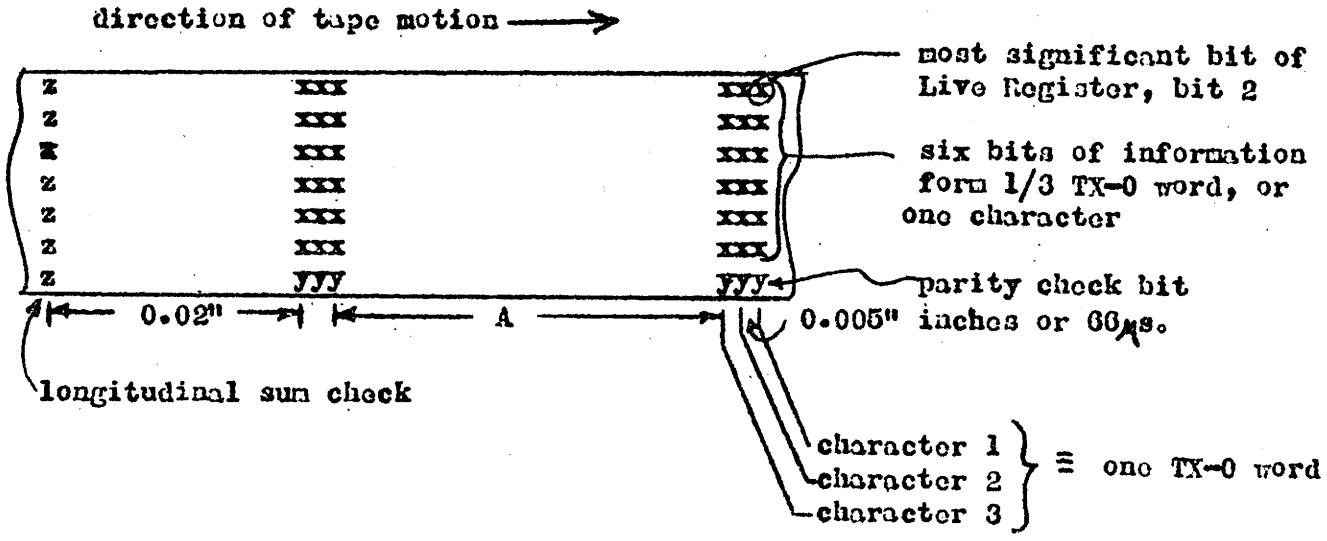


Figure 3

The distance A in Fig. 3 may be varied in length by the program, but must lie in the range 66 μs. to 264 μs. (both time limits are determined automatically by the system). The parity or redundancy check is computed so that there is an odd number of ones appearing laterally across the seven channels of the recorded character.

When information is written, character 1 of Fig. 3 is written from bits 2, 5, 8, 11, 14 and 17, character 2 is from bits 1, 4, 7, 10, 13 and 16, and character 3 is formed from bits 0, 3, 6, 9, 12, and 15 of the Live Register. The information is read back into these same bit positions of the Live Register. All reading and writing is done by the transfer of information in bits 2, 5, 8, 11, 14 and 17 together with appropriate cycle right subcommands. Henceforth, information can be thought of in terms of the three character groups, or TX-0 words.

The longitudinal check sum appears 0.02" behind the last character of the last written word. This sum is adjusted longitudinally for each of seven channels independently, such that an even number of ones appears along the tape in each track.

The Copy Instruction

The copy instruction, COPY (CPY), is used by the programmer to time information flow between the Live Register and a tape unit after a unit has been selected. The copy is an in-out command, specified by bits 4-8 of an operate instruction and other operate micro commands may be combined with it. Each time a TX-0 word is to be written on tape, a CPY is given. A copy order must be given once for each word transferred.

The distance A of Fig. 3 may be varied in length, but, if a CPY is given too soon after a previous CPY, the latter order is held up so that time A will be 66 μs. When writing, if a CPY is not given for 396 μs, a one character longitudinal sum check is written .02 inches (or 264 μs) behind the last character written from the previous CPY.

When information is read into the Live Register, the CPY provides the signal to the program to indicate that three characters have entered the Live Register. If a CPY is given when a unit is either in BST, RWD, RIM, or de-selected, the CPY has no effect.

Program Flags and Skip-On-Flag Orders

Program flags or indicators are flip-flops which are set by the tape unit. Orders will be provided which allow the program to skip an instruction if a flag is set to a given state. The flags or program indicators for use with the magnetic tape units are:

1. Parity or Redundancy Check (RC)Flag - This flag is set only while information is being read if any character read into the Live Register has an incorrect parity check. This will not check the longitudinal sum at the end-of-record.

2. End-of-Record (EOR) Flag - Used while information is being read. It is set if there is a gap of at least .02 inches between two characters on the tape.

3. Read-Write Select (RWS) Flag - Is used to tell the program that a unit has been deselected or stopped. A deselected unit may be re-selected by giving another select order. This flag is set during writing if a CPY has not been given soon enough, and the end-of-record has been written, deselecting the unit.

When information is being read, the RWS Flag is set if the three characters that comprise a TX-0 word are assembled in the Live Register and a CPY has not been given. The tape proceeds to the EOR and unit is deselected. When the above condition occurs, the first word of the record appears in the Live Register.

When reading information, an instruction referring to the Live Register is held up if a word is only partially assembled in the Live Register, i.e. only one or two of the three characters have been read in. In this case, since the order involving the Live Register is held up, any subsequent CPY instructions will have been given too late. (the CPY instruction must be given before the last character of the three characters which comprise a TX-0 word enters the Live Register) and the unit will go to the End-of-Record with the EOR Flag set, and the RWS Flag set, and the unit deselected. Thus, the program;

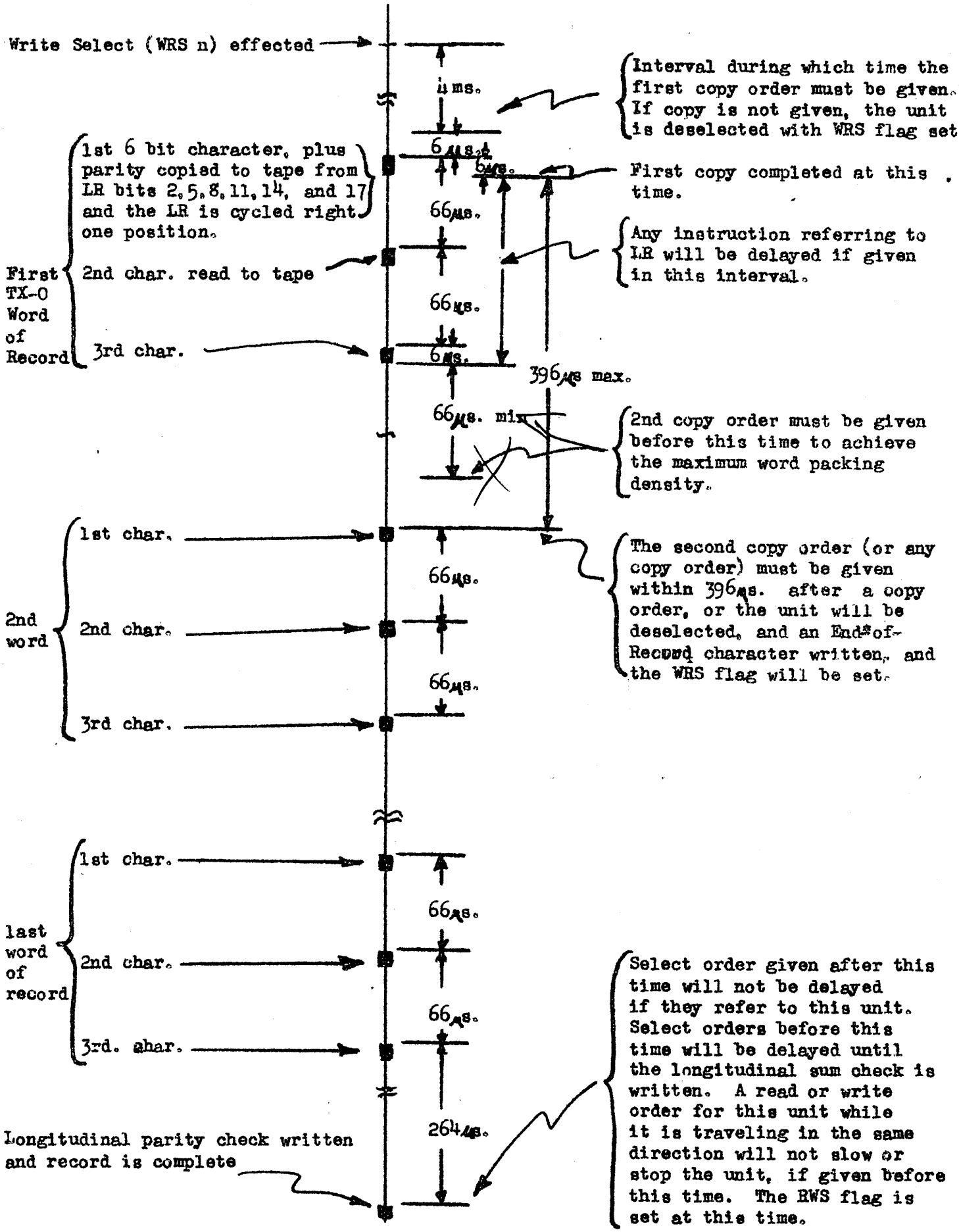
```
rds 0
slr m
```

stores the first word of the record of the tape on unit 0 in register m and the tape proceeds to the End-of-Record with the EOR and RWS Flags set, and the unit deselected.

Using the Tape Units

Writing

The general timing for writing is shown in Fig. 4. A unit is first selected by giving a WRS n order. This starts the unit in a forward direction with the write amplifiers turned on such that positive flux is being recorded on the tape in all channels. When the WRS order is given, a delay of 4 milliseconds (ms) is started automatically which allows the tape unit to come up to speed. If the delay has passed, and a CPY instruction has not been given,



Proposed Timing for the Writing Mode (WRS n)

Figure 4

the unit is deselected and the RWS Flag is set. A longitudinal sum is written (the character 000 000 0, or blank tape) .02 inches behind the tape determined by the 4 ms. ddlay. Thus, by giving several WRS n orders in sequence, blank tape may be written.

Normally the program would give a CPY before the 4 ms delay is completed in which case the computer would wait until the delay completed before obeying the CPY. After the first character relating to the CPY is written, the program proceeds until the next CPY is given. If a CPY is not given for 400 μs, the unit is deselected with the RWS Flag up, and a longitudinal sum written .02 inches beyond the last character of the final CPY. If, while information is being copied onto tape (involving writing from the Live Register and shifting), an order is given which refers to the Live Register, the order will be held up until the CPY order has been completed. Information from the TX-0 is written on tape as shown in Figure 3. A CPY instruction when the machine is in the WRS n mode automatically does the following:

1. Copies Live Register bits 2, 5, 8, 11, 14, and 17 onto the tape and cycles the Live Register right 1 position. The parity bit is computed from the other six bits and inserted. Calculations may proceed when the first character is written.

2. A 66 μs delay is inserted, and (1) is repeated.

3. Step 2 is repeated, placing a TX-0 word as three characters on the tape.

If a CPY instruction is given after the unit has been deselected, the CPY has no effect. A subroutine which would write n (n > 0) words, which were stored beginning in register j, could be called for by the MACRO, writemagtape J, N. The subroutine could be coded as follows:

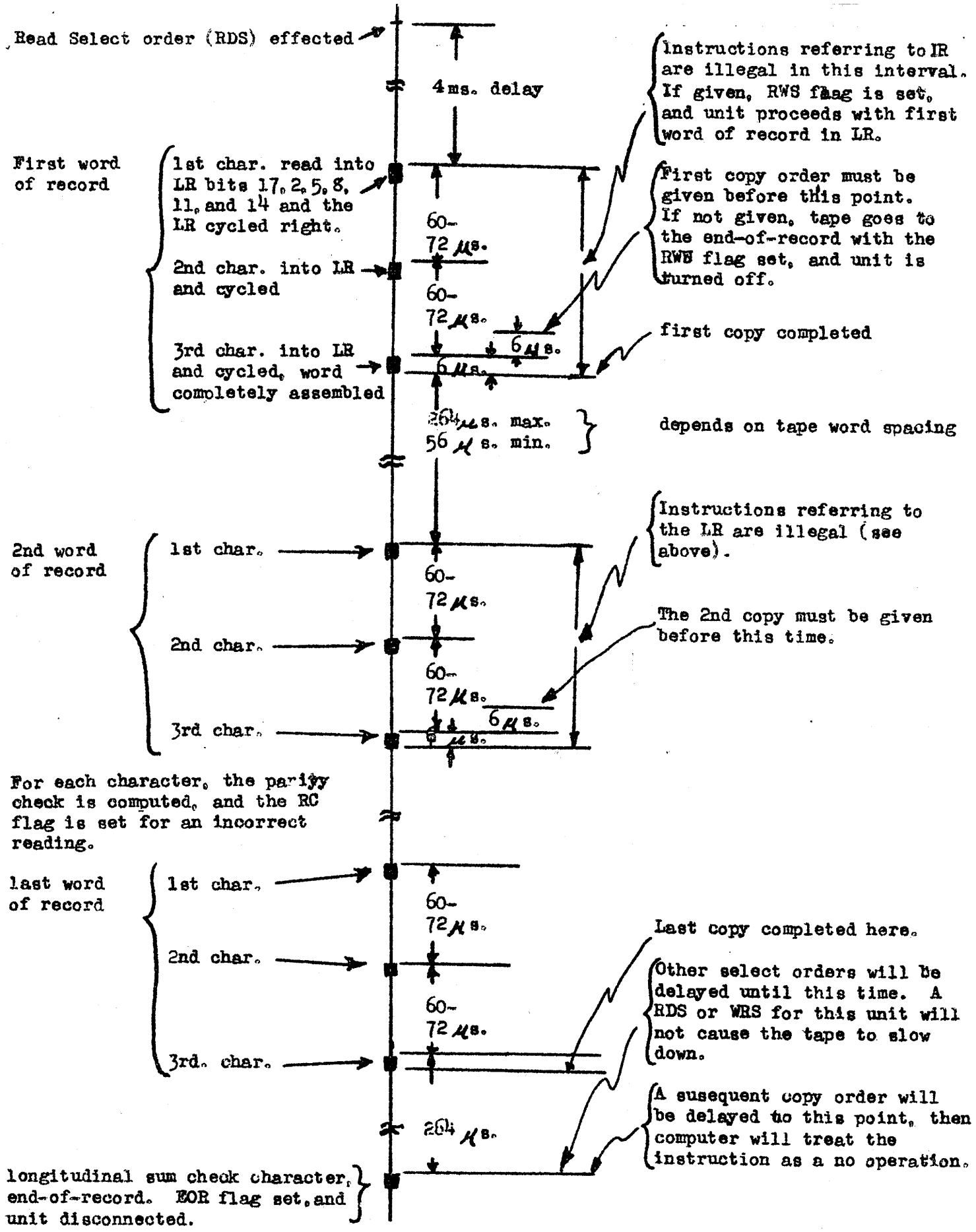
```
define
writemagtape J,N
          llr (llr J
          slr wmt+3
          cla
          add (-N+1
          llr (tra .+2
          tra wmt
          terminate

          xx=hlt

wmt,      wrs 1
          slr end
          sto end+1
          xx
          cpy
          cla
          add wmt+3
          add (1
          sto wmt+3
          cla
          add end+1
          add (1
          sto end+1
          trn wmt+3
end,      xx
          xx
```

Reading a Record

By examining the program flags, records of various kinds can be read, and forward spacing may be affected; the general timing for reading is shown in Fig. 5. The read mode is selected by a RDS n. This instruction starts the tape moving in the forward direction. An up to speed delay of 4 ms is inserted which inhibits any information from entering the Live Register,



Proposed Timing for the Reading Mode (RDS n)

Figure 5

from the tape. A CPY instruction may be given at any time after a RDS, but the CPY is not obeyed until three characters from the tape have been read into the Live Register. Any instruction affecting the Live Register is held up until the three characters are assembled in the Live Register. The parity check (RC) flag may be examined at any time (after individual CPY's, or at the end of a routine where a series of CPY's have been used), which indicates whether any of the three character groups had incorrect parity checks. There are no provisions to read or check the longitudinal sum check.

If a CPY is not given soon enough after a RDS n order, and information enters the Live Register without a CPY (the CPY is a signal to the tape that the information will be taken from the Live Register within the next 12 μs), the tape unit is deselected. The deselection causes the WRS flag to be set, and the tape moves to the end-of-the record, (.02 inch gap) before stopping. The end-of-record (EOR) flag is also set when the tape has moved to the end-of-record, under the preceding circumstances. Thus, by giving j - RDS orders, the tape unit will forward space j records. The EOR flag is set when the gap between two characters on tape is .02 inches. A CPY after a tape has been deselected has no effect.

The EOR flag is not set initially while information is entering the Live Register while the first CPY is being fulfilled, i.e., there can be any space longer than that corresponding to a 4 ms delay at the beginning of a record.

Read Subroutines

A typical subroutine to read n words from tape into a series of registers beginning with j might be programmed as follows:

```
define
readmagtape J,N
          llr (slr J
          slr rmt+4
          cla
          add (-N+1
          llr (tra .+2
          tra rmt

          xx=hlt

rmt,      rds 1
          sto eno+1
          slr eno
          cpy
          xx        | becomes slr J
          cla
          add rmt+4
          add (1
          sto rmt+4
          cla
          add eno+1
          add (1
          sto eno+1
          trn rmt+3
sk        skp rc    | skip next instruction if parity checks are ok
          hlt       | hlt,a bad bit has been read
eno,      xx        | link for the subroutine
          xx        | count for the number of words to be read
```

The Read-In Mode (RIM)

The Read-In Mode, unlike the present Read-In Mode for punched paper tape, can be selected as an operate command. It may also be selected by a push button on the console, or may be called for in the Test Mode by an appropriate instruction in the Test Buffer Register. Giving an RIM instruction first rewinds the tape unit to the load point. The tape is started forward

and the tape is read. If the tape is already at the load point, then the tape is read immediately. Characters on the tape are read as follows:

1. Three characters on the tape are read and interpreted either as an instruction to ser x or tra y.

2. A slr^{x} command stores the following three characters on the tape in register ^{x} of the TX-0.

3. A tra y, transfers from the RIM to register y for program.

Only unit 0 can be selected in the Read-In Mode.

Binard Coded Decimal (BCD) Information

BCD information may be written instead of straight binary by switching any of the tape units to the BCD mode. This would normally be used for the IBM peripheral equipment, since BCD 0's would become blank tape--and as such, impossible to read correctly under the present scheme of logic. The switches to transform a tape unit to the BCD mode would probably be located near the unit or on the TX-0 console.

Use With Flexowriters

A Flexowriter could be attached to a unit such that delayed printing can be done with the tape units and the Flexowriter off-line. In this case, a flexowriter character, or probably a series of three characters will compose a record, and the tape unit would have to stop between each record, in order to allow the flexowriter time to print the record.

Signed C.J. Bell

Approved J.B. Dennis