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PAPER TAPE SUBSYSTEM

The paper tape subsystem consists of two mechanically-independent units: a mechanism for reading tape at a rate of 250 or 1000 characters per second, and a mechanism for punching tape at 110 characters per second. The reader and punch are capable of reading and punching 5-, 6-, 7-, and 8-channel tape.

The subsystem receives input from and provides output to the central processor by means of reading and punching paper tape on line under program control. Access to and from the central processor and main memory is via the A and N registers as for the console typewriter, System operations using the A and N registers must stop during paper tape data transfer, but all other operations, including computation and other input/output peripheral operations can continue.

PAPER TAPE READER

The paper tape reader consists of a photoelectric reading mechanism and the reader control logic. The reader control logic interprets commands from the central processor and controls the reader mechanism, and handles parity checking, code level selection, special character control, and leader and trailer inhibit. Tape specifications are listed under the heading of "Characteristics of Paper Tape."

Reading is performed when information is detected photoelectrically as perforated tape passes between nine photodiodes and a light source. The photodiodes are aligned with the eight information channel positions and the sprocket position of the tape.

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2. Read Paper Tape (RPT)--This instruction causes the drive roller to press tape against the rotating capstan, causing the tape to move. As soon as the light source passes through a punched hole in the tape, the photodiodes route the information to the N-register. Tape continues to move and information continues to be read until a Halt Paper Tape signal is received, or until one of the following conditions is encountered:

   a. The system is put into the manual mode during paper tape reading.
   b. There is a card reader alarm.
   c. There is a card punch alarm.
   d. There is a parity error connected with either memory or the N-register when the STOP ON PARITY ALARM/NORM switch on the computer console has been set to STOP ON PARITY ALARM.

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   c. There is a card punch alarm.
   d. There is a parity error connected with either memory or the N-register when the STOP ON PARITY ALARM/NORM switch on the computer console has been set to STOP ON PARITY ALARM.

3. Halt Paper Tape (HPT)--This instruction terminates reading and stops tape movement. It does this by releasing the pinch roller and by activating the brake. When reading at a speed of 250 characters per second, the tape stops on the last character read. When reading at a speed of 1000 characters per second, at least two characters pass the read station before tape stops.

PAPER TAPE PUNCH

The paper tape punch consists of the tape punching mechanism and punch control logic which interprets commands from the central processor and controls the punching operation. The punch is capable of punching 5-channel, or 6-, 7-, and 8-channel tape at a maximum rate of 110 characters per second. The sprocket hole (feed hole) channel and a maximum of eight information channels (or seven plus a parity channel) can be punched under program control. Information is fed from the 6-bit N-register to the punch mechanism. The steps of a punch operation are described under the headings of the applicable program instructions as follows:

1. Punch Power On (PON)--When executed by the central processor, the instruction connects the paper tape punch to the N-register and disconnects all other N-register peripheral units. A delay of 500 ms must be programmed before issuing a WPT command.

2. Write Paper Tape (WPT)--This instruction is given for each character to be punched because the punch punches one character and halts. The instruction causes the information in the N-register to be channeled to the punch magnets. The information is then punched and the tape is fed forward one position, to the next sprocket hole position.

3. Input/Output Power Off (OFF)--This instruction disconnects the paper tape punch from the N-register, turns off power to the punch, and places the N-register in a not-ready condition.

TAPE SPECIFICATIONS

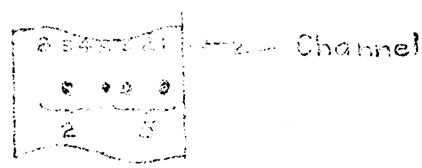
Paper tape must have a hard, smooth, dull finish, and be oil impregnated. It should be opaque and as free from extraneous and unbeaten fibers as possible. The following is a list of the exact tape specifications:

1. Width: 5-channel, 11/16 inch
   6-, or 7-channel, 7/8 inch
   8-channel, 1 inch (one-inch tape may also be used for 6-, or 7-channels)
2. Punching density: 10 characters per linear inch
3. Spacing across tape width: 0.1 inch from hole center to hole center
4. Code hole: 0.072 inch diameter
5. Sprocket hole: 0.046 inch diameter
6. Thickness: 0.0040 ($\pm$0.0003) inch
7. Optical transmittance: 40% maximum
8. Colour: black, blue, green, grey, or pink.

PAPER TAPE CODES AND CODE CONVERSION

Channels in paper tape are the longitudinal rows where holes may be punched along the length of the tape. These channels are usually referred to by number, as is indicated across the top of the tapes in Figures 1 and 2. Information is recorded in each channel by either punching a hole or leaving the position unpunched. Each hole in the tape represents a 1-bit sent to or from the N-register of the central processor during tape reading or punching. A code character is read from each frame in the tape. A frame is the combination of holes and spaces in a transverse column of one or more channels.

In many cases it is sufficient to identify tape frames by specifying the location of punched holes corresponding to channel numbers. However, the identification of punched information is often facilitated by reading tape frames in the octal interpretation of the punched binary code. For example, a "one" punch represents an octal 1, a "two" punch represents an octal 2, and a "one, three" punch represents an octal 5. In 6-channel code, holes from rows 1, 2 and 3 (see Figure 2) are read in binary to obtain the least significant octal digit, and holes from rows 4, 5 and 6 are read in binary to obtain the most significant octal digit. The sprocket hole is ignored in reading tape. The following frame illustrates the 6-channel punched configuration of an octal 25.



There are a few basic considerations regarding tape codes. These are:

1. A tape user must always know which code is used in reading or punching. There should never be any doubt about the meaning of a particular configuration either on tape, in the N-register, or in computer memory.

2. Tape codes may have to agree with other codes used in memory. The most common memory code is the binary-coded decimal (BCD) character code. It is only necessary that tape codes be converted to agree with other memory codes if there is some joint use made of the information, as when there are calculations or comparisons of information.

3. Tape codes may have to be converted to another code if there is output of paper tape information to a subsystem other than the paper tape punch. For example, the high speed printer information is intelligible only when it is in BCD form.

Conversion of paper tape codes during either input or output of information is relatively simple, for there are utility routines to perform the necessary conversions.

FIVE-LEVEL CODE. Although there may be great flexibility in use of paper tape codes, there are some codes which are considered to be more or less standard. One of these codes is the 5-level code which has been used in the communication field ever since the code was introduced in 1870.

SEVEN- AND EIGHT-LEVEL CODES. The tapes for 7- and 8-channel codes are identical with the exception that 8-channel tape has a carriage return code (octal 100). The 7- and 8-level codes have an error-checking feature (the parity bit) which permits detecting parity errors arising during input and output. Another advantage of 7- and 8-level code over 5-level code is that no figure or letter shift characters need to be used.

Parity Generation and Error Detection

Parity is generated and detected on 7- and 8-channel tape, but not on 5- and 6-channel tape. When information is punched on 7- or 8-channel paper tape, an odd parity bit is punched in channel 5 as necessary to produce an odd configuration of 1-bits in a frame. When data is read, each configuration is checked for the proper parity. The parity bit, when present, does not enter the N-register, but the detection logic of the paper tape subsystem senses whether a parity bit should or should not have been detected or generated.

When a parity error is detected during the reading of paper tape, a signal is sent to the central processor which lights the PARITY alarm indicator on the GE 225 control console. Central processor and paper tape reader operations halt on detection of a parity error if the STOP ON PARITY ALARM/NORM switch was set to STOP ON PARITY ALARM or if the programmer has programmed a stop on parity alarm. Otherwise, the parity error will have no effect on the continuation of paper tape operations.

Because channel 5 is reserved for the parity bit, the octal interpretation of tape characters must take channels 4, 6, and 7 for the most significant octal digit, as is illustrated in Figure 3.

FIG 3 - 7-channel tape.

Delete Code

The delete code (octal 77) is used to void information on the tape by preventing any of the data from going to the N-register. It can be used with either 7- or 8-level tape. When this octal 77 code is read, no information is sent to the N-register.

Special Character Control

A special character in the normal mode is the single punch in channel 8 (octal 100) This, of course, is found only on 8-channel tape. The 8-punch is sensed by the special character control logic of the paper tape subsystem, and causes six 1-bits to be sent to the N-register. Parity is not involved, since the parity checking logic is disabled. Only with 8-channel tape can an octal 77 be sent to the N-register in the normal mode.

Tape Leader and Trailer Inhibit

The leader and trailer portions of tape have sprocket holes but have no other punches representing data. In 7- and 8-level tape, the paper tape reader detects the presence of sprocket holes without data punches. When it does this, it prevents the N-register from becoming ready and thereby prevents information from being shifted into N. The net effect is an ignoring of the portions of tape which have only sprocket holes. When a space is represented on 7- and 8-channel tape, a parity bit is present. It is the parity bit which differentiates between a frame on the leader or trailer and a space.

TIMING CONSIDERATIONS

When reading of paper tape is initiated by an [illegible] instruction, there is a continuing flow of information from paper tape to the N-register. Information is transmitted each time a frame with one or more punched holes passes the read station. The timing of the flow of information is controlled by the sprocket hole of the tape as follows:

1. Each time the light source of the reader detects the leading edge of a sprocket hole, it triggers the sending of information from that frame on the tape to the N-register. The information goes to N whether N is ready or not, and whether N is full or empty. This means that the program must empty the N-register before the leading edge of the next sprocket hole is detected by the reader. If N is not emptied in time, a character moved into N will overlay the previous character, and the overlaid character will be lost. Parity errors also occur as information is overlaid. The time interval between sprocket holes, during which the N-register must be emptied before the next character from paper tape enters the register, is 2 milliseconds when reading is at the rate of 250 characters per second. It is 500 microseconds when reading is at 1000 characters per second.

2. The detection of the trailing edge of the sprocket hole halts the transfer of that frame of information to the N-register.

3. The detection of the trailing edge of the sprocket hole also causes the N-register to become <u>ready</u>. The ready condition indicates that N is fully loaded and one frame has been read from paper tape. This condition can be tested by the program and can be seen on the console of the central processor when [illegible] READY glows green.

It should be noted that the sprocket hole can create a ready condition but it cannot cause a return of the N-register to a not-ready condition. A shift N and A Right (SNA) instruction is required to cause the N-register to become not ready. This SNA instruction should be given as soon as the N-register becomes ready. When this is done, there will be no N-register overlay. Care should be taken after the shift to limit any processing loops (such as character validity and parity checks) to less than the allowable time interval. The HPT instruction must be given to stop paper tape movement.

DATA TRANSFER DURING READING

During a paper tape reading operation, information is transferred without a parity bit from tape to the N-register. An RPT instruction initiates the reading. Information is then transferred from the N-register to the A-register by an SNA instruction. If information read into N is to be immediately typed out or punched, the N- to A-shift is not necessary. The relative bit positions of a character on paper tape are unchanged when the character is read from tape to the N-register, and shifted into the A-register. The information in the A-register is stored by an STA instruction after one, two, or three paper tape characters are transferred from N to A, depending upon the programmer's choice of memory word format. If the shifts from the N-register to the A-register are performed in the normal mode on three successive paper tape characters by SNA 7, SNA 6, and SNA 6, or an SNA 6 three times followed by an SNA 1, the word format from 6-, 7-, or 8-channel tape would be the following

A Register

S	1	2 ——→ 7	8 ——→ 13	14 ——→ 19
X	0	3rd Tape Character	2nd Tape Character	1st Tape Character

Information cannot be transferred into the sign position of the A-register by use of an SNA instruction. Unless the A-register was cleared before its use, the sign remains unchanged from its previous use. When three paper tape characters are positioned in A(2-19) as illustrated, a zero automatically enters bit position 1 at the time of the last shift. The format of a word which has only one paper tape character is most often as follows (the shift from the N to the A register in this case is SNA 19).

	S	1 ——— 13	14 ——— 19
A Register	x	0 ——— 0	Tape Character

Since information transfer from paper tape to the N-register differs according to the code level used, each tape format is described and illustrated and its special characteristics listed (except for 5-level code, which is described separately).

Summary of 6-Level Code Reading

In 6-level code reading:

1. All six information channels from paper tape enter the N-register as shown in Figure 4.
2. There are no illegal code combinations.
3. Six zeros are read into the N-register when a sprocket hole of a leader or trailer is sensed.
4. There is no parity check.
5. There is no delete code.
6. The highest number which can be read is octal 77.

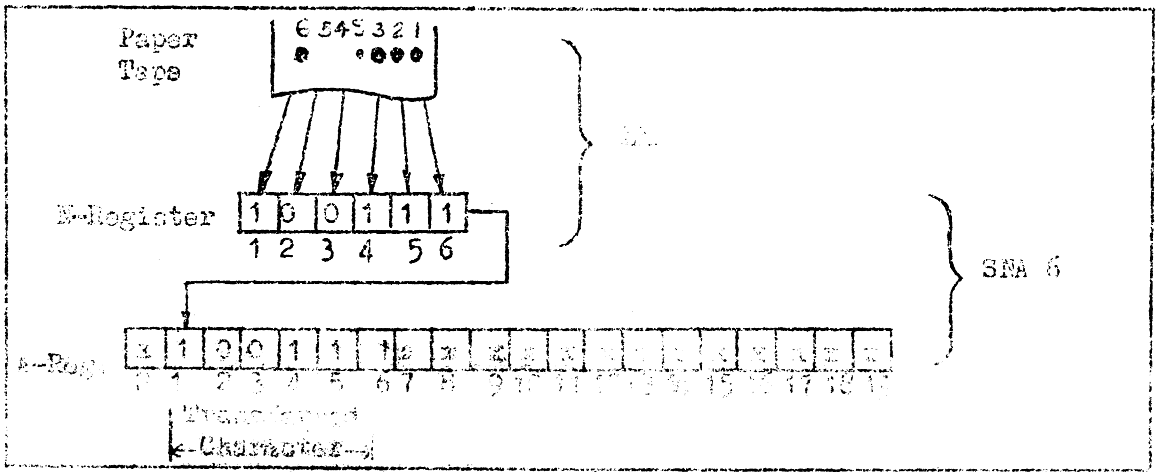


Figure 4 -- Reading 6-Level Paper Tape

Summary of 7-Level Code Reading

The reading of 7-level code may be summarized as follows:

1. In reading 7-level code in the normal mode, channel five of the paper tape is not read into the N-register. The presence or absence of the parity bit (P) is sensed by the control logic without requiring the information from channel 5 to be transferred. Information flow from paper tape to the six positions of the N-register is illustrated in Figure 5.
2. The paper tape reader ignores the leader and trailer ends of the tape (when only sprocket holes pass the read station). No information is transferred to the N-register.
3. A frame of paper tape having only a parity punch is read into the N-register as all zeros.
4. When all seven channels are punched in a frame of paper tape, the normal mode of reading sends no information to the N-register. Thus all-1's configuration on tape is used as a delete code.

5. The highest number which can be read in the normal mode is octal 76.
6. Figure 5 illustrates the manner in which information is read from paper tape into the N-register and shifted from the N-register to the A-register.

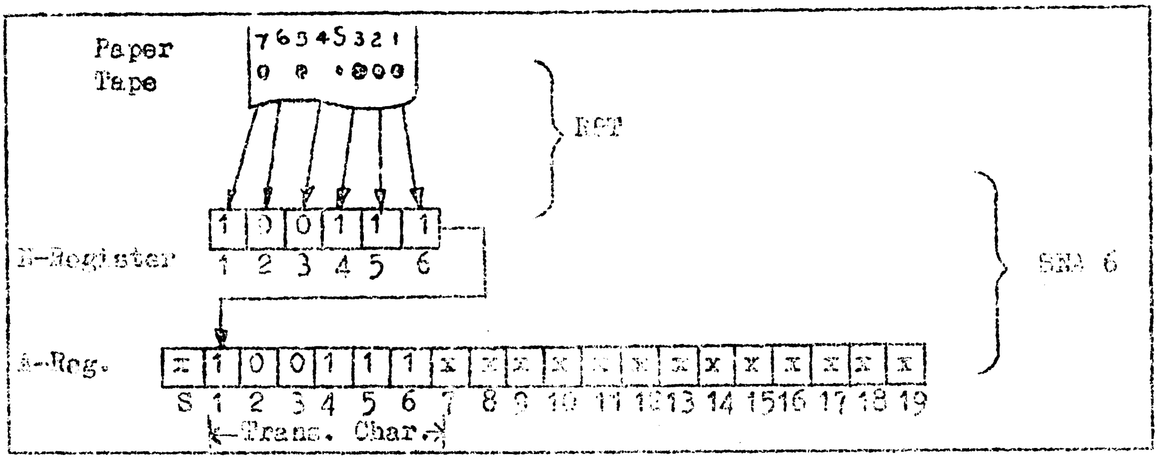


Figure 5 - Reading 7-Level Paper Tape

Summary of 8-Level Code Reading

The reading of 8-level code may be summarized as follows:

1. With few exceptions, 8-level code is read in the same way that 7-level code is read. Channel 5 on tape contains the parity bit. The transfer of information in the normal mode is the same as is illustrated in Figure 5 with one exception. The exception is the special character ccontrol which senses a hole punched only in channel 8 and causes six 1-bits to be placed in the N-register. Figure 6 illustrates this special character transfer. No parity bit is involved in the special character.
2. All code combinations which contain an 8-channel punch plus any other channel punch are considered invalid. Invalid codes are not transmitted to the N-register.
3. The paper tape reader ignores the leader and trailer ends of the tape.
4. A frame of paper tape having only a parity punch is read into the N-register as all zeros.
5. When all seven channels are punched in a frame of paper tape, no information is sent to the N-register during the normal mode of reading. This all-1's configuration on tape is used as a delete code.
6. The highest number which can be read in the normal mode is octal 77.

DATA TRANSFER DURING PUNCHING

During a paper tape punching operation, characters must first be positioned in the A-register. One character at a time is transferred from the A-register to the N-register by an SAN instruction and from the N-register to paper tape by a WPT instruction. With one exception, the relative bit positions of a character in the A-register are unchanged when the character is shifted from the A-register to the N-register and transferred from the N-register to paper tape. The exception is that a parity bit is added as necessary to cause an odd number of punches when information is transferred from the N-register in 7- and 8-level codes.

The sign bit in the A-register does not shift and does not change as characters are shifted out of A. Vacated positions in A are filled with 0-bits if the sign is positive and with 1-bits if the sign is negative. If the A-register contains three characters right-justified, a normal mode transfer to the N-register is in the following order:

	S	1	2 – 7	8 – 13	14 – 19
A-Register	X	X	3rd Character	2nd Character	1st Character

Assuming that the sign is positive and the bit in position 1 is unknown, the A-register shown above would contain the following configuration after an SAM 6 instruction:

	S	1 – 7	8 – 13	14 – 19
A-Register	0	0 0 0 0 0 0 X	3rd Character	2nd Character

Notice that the bit originally in position 1 remains unchanged as it shifts. Since information transfer differs according to the code level used, each tape format is described and illustrated separately (except for 5-level code, which is described separately).

Summary of 6-Level Code Punching

In 6-level code punching:

1. Six channels are punched in paper tape as is shown in Figure 6.
2. The paper tape punch feeds tape to create a leader or a trailer (sprocket hole only) when the N-register contains 111111.
3. There is no parity check.
4. There is no delete code.
5. The highest number which can be punched is octal 76.

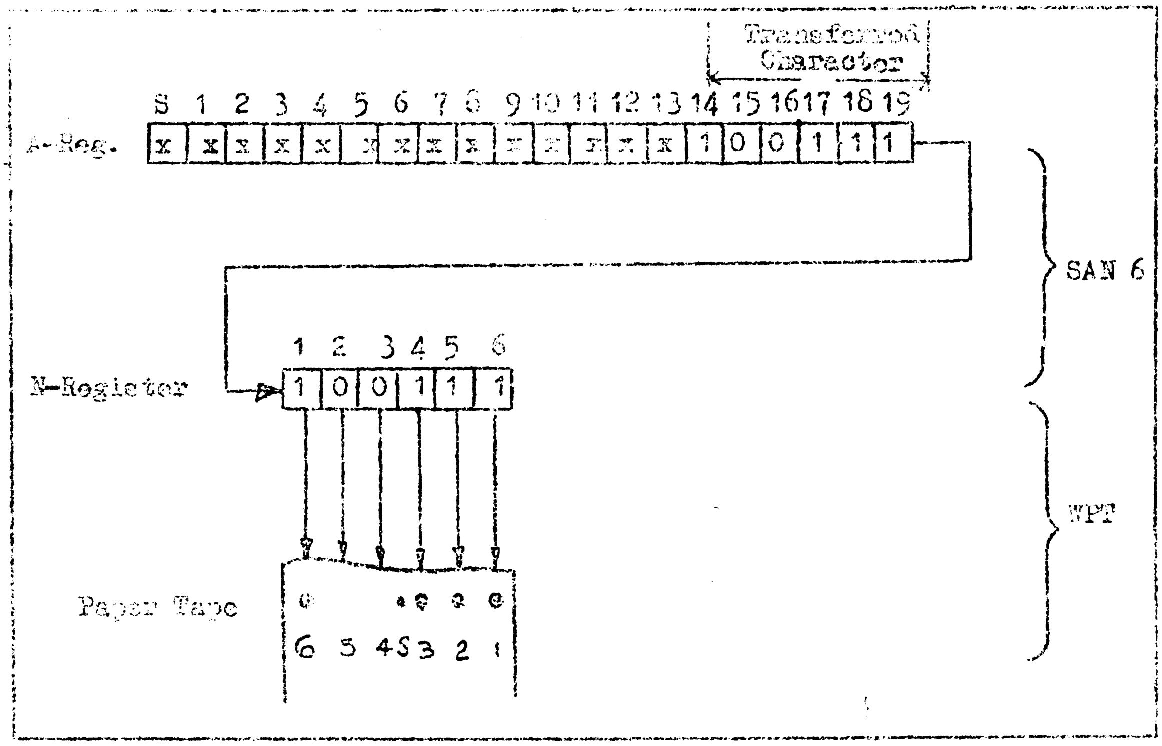


Figure 6 - Punching 6-Level Paper Tape

Summary of 7-Level Code Punching

The punching of 7-level code may be summarized as follows:

1. The normal mode of punching causes a parity punch to be added in channel 5 each time a parity check shows that the N-register contains an even number of 1-bits. This makes the total number of holes in a paper tape frame odd. The use of channel 5 for parity prevents its use for data, causing channel 6 to receive data from N2 and channel 7 to receive data from N1. This is illustrated in Figure 7.
2. The configuration of 111111 in the A-register causes a leader or a trailer (sprocket hole only) to be punched.
3. A zero in the normal mode is punched as a parity punch only.
4. The highest number which can be punched in the normal mode is octal 76.
5. Figure 7 illustrates the manner in which information is shifted from the A-register to the N-register and punched in paper tape.

Summary of 8-Level Code Punching

The punching of 8-level code may be summarized as follows:

1. With few exceptions, 8-level code is punched in the same way that 7-level code is punched. The parity bit is punched in channel 5. Transfer of information in the normal mode is the same as is illustrated in Figure 7 with one exception. The exception is that a character

consisting of 1-bits (111111) sent to the N-register is punched as a channel 8 punch only. Figure 8 illustrates this special character transfer. No parity bit is involved in the transfer.

2. A zero is punched in the normal mode as a parity punch only.

3. The highest number which can be punched in the normal mode is a single punch in channel 8 which is octal 100.

4. It is not possible to program the punching of a leader or a trailer (sprocket hole only).

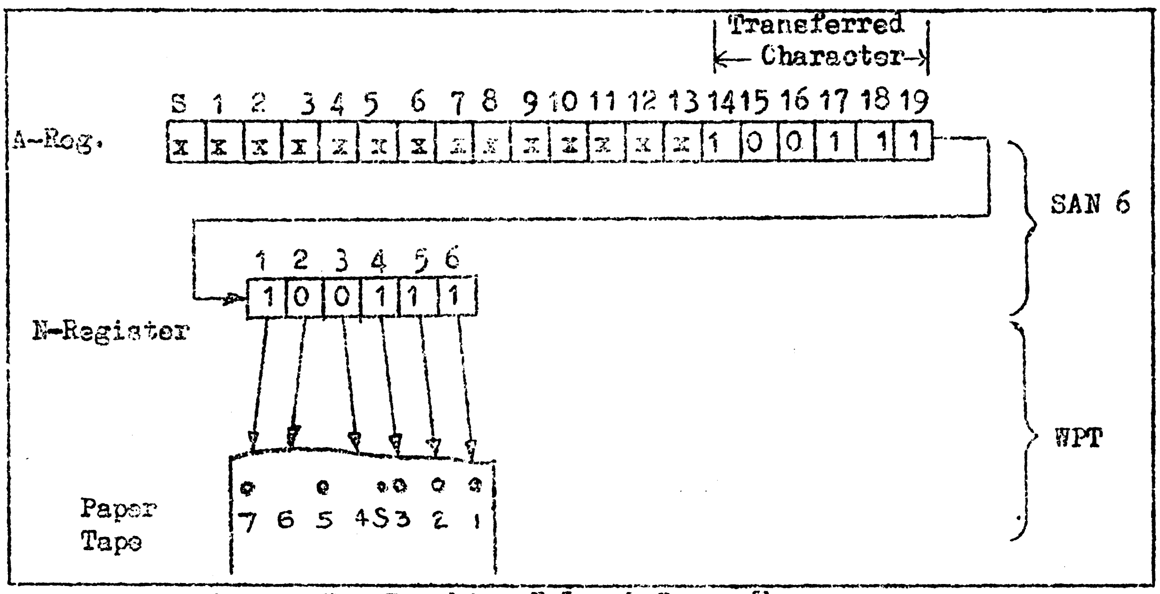


Figure 7 - Punching 7-Level Paper Tape

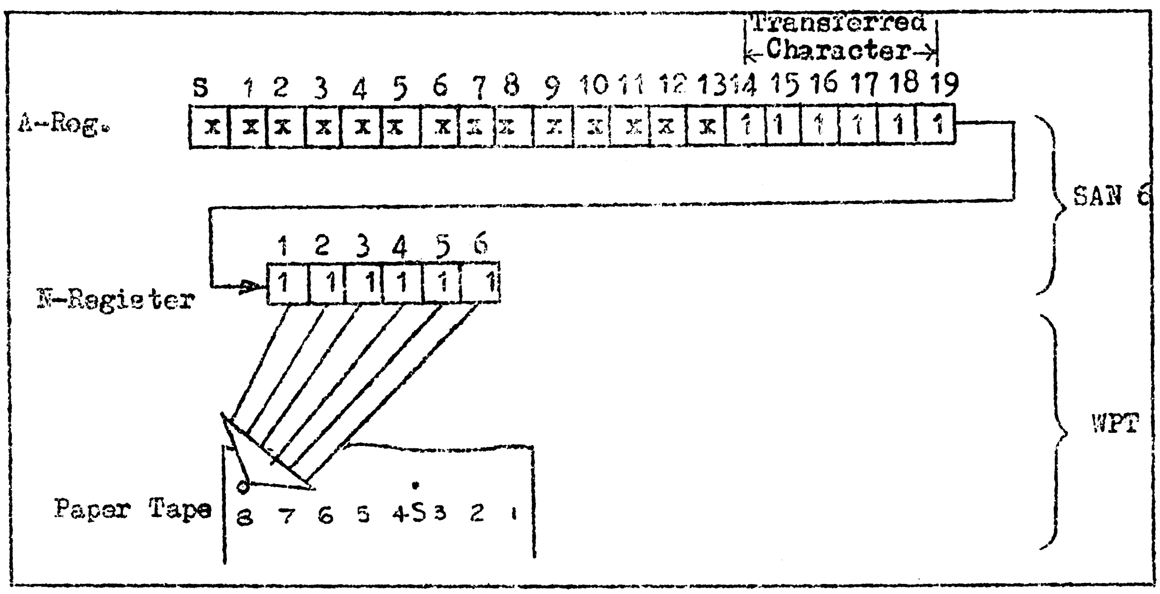


Figure 8 - Special Character Punching 8-Level Code

FIVE-CHANNEL PAPER TAPE

The 5-channel paper tape code is the shortest of the paper tape codes because each punched configuration may have two different meanings, depending upon whether the machine has been shifted into upper case or lower case by a preceding code. To designate upper or lower case in a program, the programmer must use the "letter shift" code (octal 36) to designate upper case, and the "figure shift" code (octal 33) to designate lower case. Just as with the teletype or typewriter, a shift to upper case means that every character following the shift is upper case until a lower case shift is given. Likewise, everything following a lower case shift is lower case until the upper case shift is given. Failing to give the shifts at the proper time causes errors in the interpretation of the data punched or read.

5-Channel Code

The code as used by the University of Queensland Computer Centre is shown in Figure 10. All the digits and the special characters +, - and . have an odd number of one-bits in the representation in order to aid checking by program for numeric (dats) input. There is no parity checking on 5-channel tape.

Conversion of BCD to 5-Channel Tape Output

If the information in memory is to be punched on 5-channel tape in the 5-channel code, there must be a code conversion. Figure 10 contains the output code which represents in octal the information which must be in the N-register in binary to punch the specified character. The following example illustrates the use of the Figure 10.

Problem: If the numeral 3 is to be punched on 5-channel tape, what configuration must be sent to the N-register to punch the 3?

Solution: The first column for lower case codes in Figure 10 contains the number 3. Opposite the 3 in the next column to the right is the octal representation for the BCD emmory code for 3. This is 03, which represents a binary 000011 in memory. In the next column to the right is the octal representation for the 5-level code. This code is 23, which represents 10011 in the N-register. It must be remembered that only N2 through N6 are used. In order to punch 03, the memory configuration 000011 must be converted to 10011 prior to sending it to the N-register, and the previous shift character must have been a figure shift. This conversion is normally done by the routine WPT.

CONVERSION OF 5-CHANNEL TAPE INPUT TO BCD

If information from 5-channel tape is to be used in memory along with other memory information (information not read from paper tape), tape information must be converted to the configuration of memory BCD characters. Likewise, if information from 5-channel tape is to be used in some other form of output, for example as printed output, it must also be in the configuration of memory BCD characters. Figure 10 lists the codes used when reading tape.

An example of the use of the table follows:

Problem: When the letter S is read from paper tape into memory, what must the memory configuration be to print the letter S on the high-speed printer?

Solution: It is first seen from Figure 10 that the letter S is in the "letter shift" half of the table and must have been preceded by a letter shift character. The fourth column of the table shows that the octal representation of the letter S (opposite S in the first column) is 23. This means that 10011 is sent to the N-register when the letter S is read from paper tape. The third column of the table indicates that octal 62 represents the 6-bit binary code required in memory to represent the letter S. The memory configuration for the character must therefore be 110010 to print the letter S. This conversion is normally done by the HPT S/R.

DATA TRANSFER-PUNCHING

The first step in punching paper tape is to position characters in the A-register. The following illustrates the A-register, which has three characters right-justified and labeled in the order in which the characters will be punched.

	S	1	2	3 ⟷ 7	8	9 ⟷ 13	14	15 ⟷ 19
A-Register	x	x	0	Third Character	0	Second Character	0	First Character

Notice that bit positions 2, 8, and 14 contain zeros. Characters are kept in 6-bit configuration to facilitate conversions to BCD memory code or other codes which require 6 bits per character. Actually, no confusion would result if 1-bits were in positions 2, 8, and 14 of the A-register. Information from these positions transfers from the A-register to the N-register but does not transfer from N1 to paper tape. The sign bit in the A-register does not shift and does not change as characters are shifted out of A. Vacated positions in A are filled with 0-bits if the sign is positive and with 1-bits if the sign is negative. The following is what the A-register just illustrated would contain after the execution of an SAN 6 instruction, providing the sign of A was negative.

	S	1 2 ... 7	8	9 ... 13	14	15 ... 19
A-Register	1	1 1 1 1 1 1 x	0	Third Character	0	Second Character

The bit which was originally in position 1 remains unchanged as it shifts. If the A-register had been cleared to zero before characters were shifted into it, bit position 1 would contain a zero before the execution of SAN 6 and bit position 7 would have a zero after the execution of SAN 6. The transfer of information from the A-register to paper tape via the N-register during punching is illustrated in Figure 11. The transfer to the N-register is made by a Shift A and N Right instruction. Transfer from the N-register to paper tape is made by a Write Paper Tape instruction.

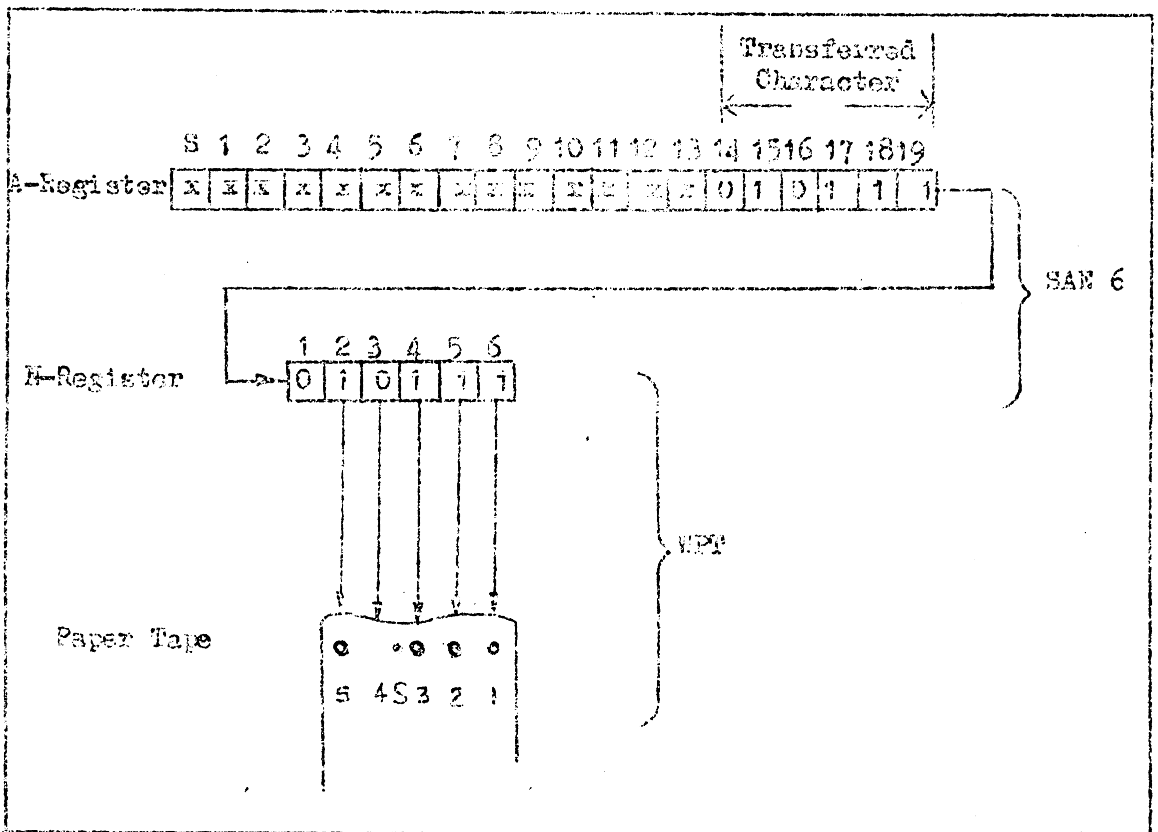


Figure 11 - Punching 5-Level Paper Tape

The following list summarizes information which applies especially to punching 5-level paper tape code:

1. The paper tape punch punches only sprocket holes to create a leader or a trailer when the N-register contains 000000 at the time WPT is executed.

2. No parity bit is on paper tape and no parity check is made.

3. Any configuration in N2 - N6 is punched by execution of WPT (there are no invalid codes).

4. The highest number which can be punched is octal 37.

5. A letter shift or figure shift code must be used to differentiate between upper and lower case codes.

DATA TRANSFER-READING

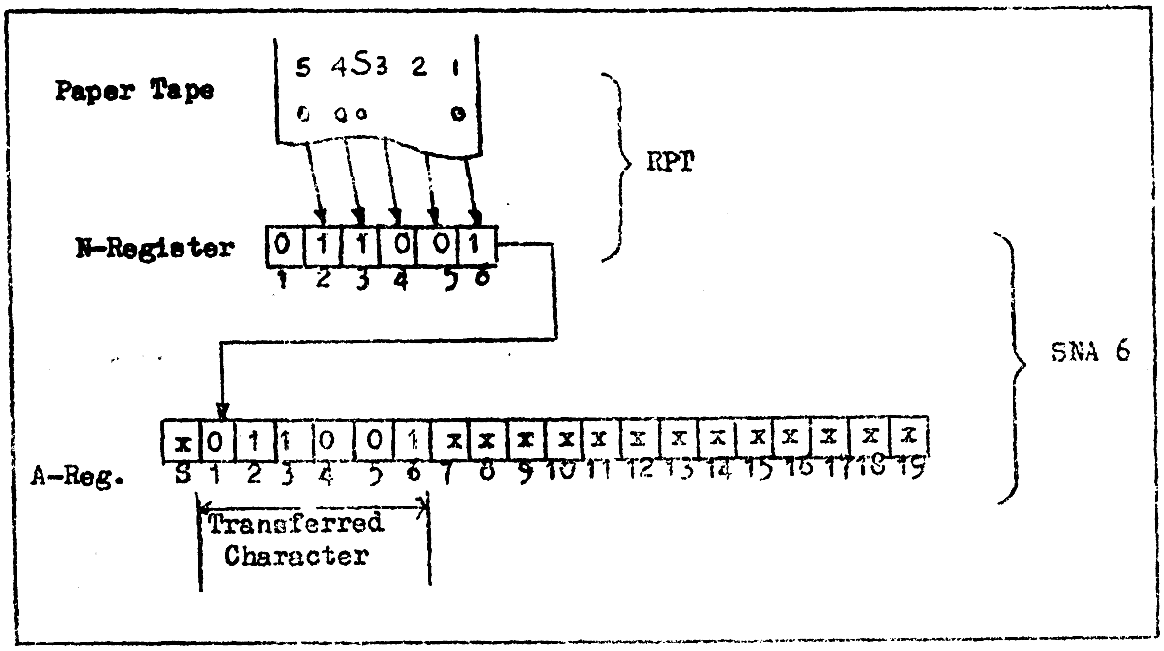
When five bits of information are transferred into the N-register from a paper tape character, a zero automatically fills the first position of the register. Three tape characters can then be placed in the A-register in the following configuration by use of the successive shift instructions SNA 7, SNA 6, and SNA 6. Each time, all six bits including the zero shift from N. This configuration facilitates conversion of 5-bit tape codes to 6-bit BCD characters.

	S	1	2	3 ←→ 7	8	9 ←→ 13	14	15 ←→ 19
A-Register	x	0	0	3rd Tape Character	0	2nd Tape Character	0	1st Tape Character

The SNA instruction does not shift information into the sign position of the A-register. Unless the A-register was cleared to zero before its used, the sign remains unchanged from its previous use. The format of a word which has only one paper tape character placed in the A-register by an SNA 19 instruction is as follows:

	S	1 ←→ 13	14 ←→	19
A-Register	x	0 ←→ 0	0	Tape Character

The transfer of information from paper tape to the A-register via the N-register during the reading of 5-level tape code is illustrated in Figure 12. Transfer to the N-register is initiated by a Read Paper Tape instruction. Transfer from the N-register to the A-register is made by a Shift N and A Right instruction.



The following list summarizes information which applies especially to reading 5-level paper tape:

1. The reader sends 000000 to the N-register when only a sprocket hole (as in the leader or trailer) is sensed.

2. No parity check is made and no parity bit is on tape.

3. Every configuration on paper tape is considered valid and is transferred to the N-register.

4. The highest number which can be read is octal 37.

5. A letter shift or figure shift must be used to differentiate between upper and lower case codes.

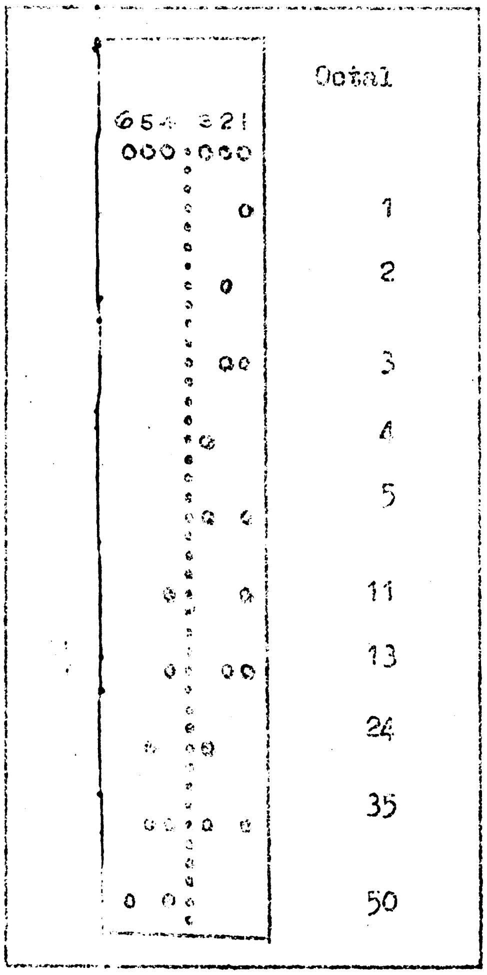


Figure 1. Paper Tape Characters
Read in Octal

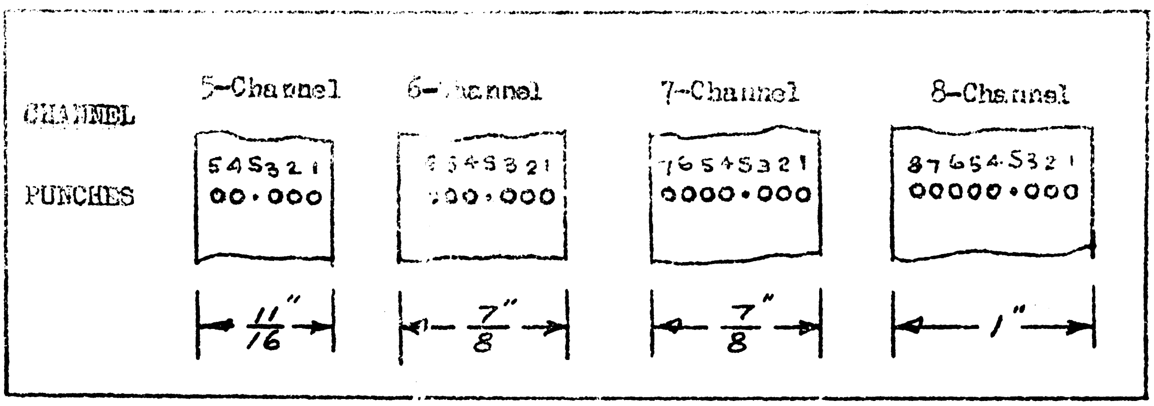


Figure 2. Paper Tape Formats

CHARACTER	B.C.D. MEMORY (OCTAL)	5-CHANNEL PAPER TAPE (OCTAL)	
		FIGURE SHIFT	LETTER SHIFT
Figures:			
0	00	20	
1	01	01	
2	02	02	
3	03	23	
4	04	04	
5	05	25	
6	06	26	
7	07	07	
8	10	10	
9	11	31	
10			
11			
Letters:			
A	21		01
B	22		02
C	23		03
D	24		04
E	25		05
F	26		06
G	27		07
H	30		10
I	31		11
J	41		12
K	42		13
L	43		14
M	44		15
N	45		16
O	46		17
P	47		20
Q	50		21
R	51		22
S	62		23
T	63		24
U	64		25
V	65		26
W	66		27
X	67		30
Y	70		31
Z	71		32

Figure 10. University of Queensland
5-Channel Paper Tape Code

SPECIAL CHARACTERS:	B.C.D. MEMORY (OCTAL)	PAPER TAPE 5-CHANNEL	
		FIGURE SHIFT	LETTER SHIFT
SPACE	60	34	34
-	40	13	
+	20	32	
/	61	27	
*	54	03	
.	33	15	
,	73	17	
=	13	12	
(	74	05	
)	34	06	
~	15	21	
#	16	11	
£	53	22	
'	14	24	
:		16	
□		30	
Δ		14	
@	14		
%	17		
CONTROL CHARACTERS:			
FIGURES		33	33
LETTERS		36	36
C.R./L.F.	37	35	35
BLANK/DELAY	77	00	00
ERASE		37	37
PRINT RED	72		
PRINT BLACK	75		
TAB	76		
C.R.	37		

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PAPER TAPE SUBSYSTEM

The paper tape subsystem consists of two mechanically-independent units: a mechanism for reading tape at a rate of 250 or 1000 characters per second, and a mechanism for punching tape at 110 characters per second. The reader and punch are capable of reading and punching 5-, 6-, 7-, and 8-channel tape.

The subsystem receives input from and provides output to the central processor by means of reading and punching paper tape on line under program control. Access to and from the central processor and main memory is via the A and N registers as for the console typewriter, System operations using the A and N registers must stop during paper tape data transfer, but all other operations, including computation and other input/output peripheral operations can continue.

PAPER TAPE READER

The paper tape reader consists of a photoelectric reading mechanism and the reader control logic. The reader control logic interprets commands from the central processor and controls the reader mechanism, and handles parity checking, code level selection, special character control, and leader and trailer inhibit. Tape specifications are listed under the heading of "Characteristics of Paper Tape."

Reading is performed when information is detected photoelectrically as perforated tape passes between nine photodiodes and a light source. The photodiodes are aligned with the eight information channel positions and the sprocket position of the tape.

The steps of a read operation are described under the headings of the applicable program instructions as follows:

1. Reader On (RON)--When executed RON turns on power to the reader, clears the N-register, removes power from the paper tape punch and typewriter, and disconnects all other N-register peripheral units. It places the N-register in a not-ready status. A delay of 200 ms. must be programmed before an RPT instruction is given,

2. Read Paper Tape (RPT)--This instruction causes the drive roller to press tape against the rotating capstan, causing the tape to move. As soon as the light source passes through a punched hole in the tape, the photodiodes route the information to the N-register. Tape continues to move and information continues to be read until a Halt Paper Tape signal is received, or until one of the following conditions is encountered:

    a. The system is put into the manual mode during paper tape reading.
    b. There is a card reader alarm.
    c. There is a card punch alarm.
    d. There is a parity error connected with either memory or the N-register when the STOP ON PARITY ALARM/NORM switch on the computer console has been set to STOP ON PARITY ALARM.

3. **Halt Paper Tape (HPT)—This instruction terminates reading and stops tape movement. It does this by releasing the pinch roller and by activating the brake. When reading at a speed of 250 characters per second, the tape stops on the last character read. When reading at a speed of 1000 characters per second, at least two characters pass the read station before tape stops.**

PAPER TAPE PUNCH

The paper tape punch consists of the tape punching mechanism and punch control logic which interprets commands from the central processor and controls the punching operation. The punch is capable of punching 5-channel, or 6-, 7-, and 8-channel tape at a maximum rate of 110 characters per second. The sprocket hole (feed hole) channel and a maximum of eight information channels (or seven plus a parity channel) can be punched under program control. Information is fed from the 6-bit N-register to the punch mechanism. The steps of a punch operation are described under the headings of the applicable program instructions as follows:

1. Punch Power On (PON)—When executed by the central processor, the instruction connects the paper tape punch to the N-register and disconnects all other N-register peripheral units. A delay of 500 ms. must be programmed before issuing a WPT command.

2. Write Paper Tape (WPT)—This instruction is given for each character to be punched because the punch punches one character and halts. The instruction causes the information in the N-register to be channeled to the punch magnets. The information is then punched and the tape is fed forward one position, to the next sprocket hole position.

3. Input/Output Power Off (OFF)—This instruction disconnects the paper tape punch from the N-register, turns off power to the punch, and places the N-register in a not-ready condition.

TAPE SPECIFICATIONS

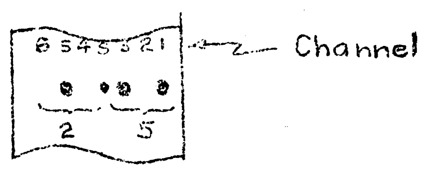
Paper tape must have a hard, smooth, dull finish, and be oil impregnated. It should be opaque and as free from extraneous and unbeaten fibers as possible. The following is a list of the exact tape specifications:

1. Width: 5-channel, 11/16 inch
   6-, or 7-channel, 7/8 inch
   8-channel, 1 inch (one-inch tape may also be used for 6-, or 7-channels)
2. Punching density: 10 characters per linear inch
3. Spacing across tape width: 0.1 inch from hole center to hole center
4. Code hole: 0.072 inch diameter
5. Sprocket hole: 0.046 inch diameter
6. Thickness: 0.0040 ($\pm$0.0003) inch
7. Optical transmittance: 40% maximum
8. Colour: black, blue, green, gray, or pink.

PAPER TAPE CODES AND CODE CONVERSION

Channels in paper tape are the longitudinal rows where holes may be punched along the length of the tape. These channels are usually referred to by number, as is indicated across the top of the tapes in Figures 1 and 2. Information is recorded in each channel by either punching a hole or leaving the position unpunched. Each hole in the tape represents a 1-bit sent to or from the N-register of the central processor during tape reading or punching. A code character is read from each frame in the tape. A frame is the combination of holes and spaces in a transverse column of one or more channels.

In many cases it is sufficient to identify tape frames by specifying the location of punched holes corresponding to channel numbers. However, the identification of punched information is often facilitated by reading tape frames in the octal interpretation of the punched binary code. For example, a "one" punch represents an octal 1, a "two" punch represents an octal 2, and a "one, three" punch represents an octal 5. In 6-channel code, holes from rows 1, 2 and 3 (see Figure 2) are read in binary to obtain the least significant octal digit, and holes from rows 4, 5 and 6 are read in binary to obtain the most significant octal digit. The sprocket hole is ignored in reading tape. The following frame illustrates the 6-channel punched configuration of an octal 25.



There are a few basic considerations regarding tape codes. These are:

1. A tape user must always know which code is used in reading or punching. There should never be any doubt about the meaning of a particular configuration either on tape, in the N-register, or in computer memory.

2. Tape codes may have to agree with other codes used in memory. The most common memory code is the binary-coded decimal (BCD) character code. It is only necessary that tape codes be converted to agree with other memory codes if there is some joint use made of the information, as when there are calculations or comparisons of information.

3. Tape codes may have to be converted to another code if there is output of paper tape information to a subsystem other than the paper tape punch. For example, the high speed printer information is intelligible only when it is in BCD form.

Conversion of paper tape codes during either input or output of information is relatively simple, for there are utility routines to perform the necessary conversions.

FIVE-LEVEL CODE. Although there may be great flexibility in use of paper tape codes, there are some codes which are considered to be more or less standard. One of these codes is the 5-level code which has been used in the communication field ever since the code was introduced in 1870.

SEVEN- AND EIGHT-LEVEL CODE. The tapes for 7- and 8-channel codes are identical with the exception that 8-channel tape has a carriage return code (octal 100). The 7- and 8-level codes have an error-checking feature (the parity bit) which permits detecting parity errors arising during input and output. Another advantage of 7- and 8-level code over 5-level code is that no figure or letter shift characters need to be used.

Parity Generation and Error Detection

Parity is generated and detected on 7- and 8-channel tape, but not on 5- and 6-channel tape. When information is punched on 7- or 8-channel paper tape, an odd parity bit is punched in channel 5 as necessary to produce an odd configuration of 1-bits in a frame. When data is read, each configuration is checked for the proper parity. The parity bit, when present, does not enter the N-register, but the detection logic of the paper tape subsystem senses whether a parity bit should or should not have been detected or generated.

When a parity error is detected during the reading of paper tape, a signal is sent to the central processor which lights the PARITY alarm indicator on the GE 225 control console. Central processor and paper tape reader operations halt on detection of a parity error if the STOP ON PARITY ALARM/NORM switch was set to STOP ON PARITY ALARM or if the programmer has programmed a stop on parity alarm. Otherwise, the parity error will have no effect on the continuation of paper tape operations.

Because channel 5 is reserved for the parity bit, the octal interpretation of tape characters must take channels 4, 6, and 7 for the most significant octal digit, as is illustrated in Figure 3.

FIG. 3 - 7-channel tape.

Delete Code

The delete code (octal 77) is used to void information on the tape by preventing any of the data from going to the N-register. It can be used with either 7- or 8-level tape. When this octal 77 code is read, no information is sent to the N-register.

Special Character Control

A special character in the normal mode is the single punch in channel 8 (octal 100). This, of course, is found only on 8-channel tape. The 8-punch is sensed by the special character control logic of the paper tape subsystem, and causes six 1-bits to be sent to the N-register. Parity is not involved, since the parity checking logic is disabled. Only with 8-channel tape can an octal 77 be sent to the N-register in the normal mode.

Tape Leader and Trailer Inhibit

The leader and trailer portions of tape have sprocket holes but have no other punches representing data. In 7- and 8-level tape, the paper tape reader detects the presence of sprocket holes without data punches. When it does this, it prevents the N-register from becoming ready and thereby prevents information from being shifted into N. The net effect is an ignoring of the portions of tape which have only sprocket holes. When a zero is represented on 7- and 8-channel tape, a parity bit is present. It is the parity bit which differentiates between a frame on the leader or trailer and a zero.

TIMING CONSIDERATIONS

When reading of paper tape is initiated by an RPT instruction, there is a continuing flow of information from paper tape to the N-register. Information is transmitted each time a frame with one or more punched holes passes the read station. The timing of the flow of information is controlled by the sprocket hole of the tape as follows:

1. Each time the light source of the reader detects the leading edge of a sprocket hole, it triggers the sending of information from that frame on the tape to the N-register. The information goes to N whether N is ready or not, and whether N is full or empty. This means that the program must empty the N-register before the leading edge of the next sprocket hole is detected by the reader. If N is not emptied in time, a character moved into N will overlay the previous character, and the overlaid character will be lost. Parity errors also occur as information is overlaid. The time interval between sprocket holes, during which the N-register must be emptied before the next character from paper tape enters the register, is 2 milliseconds when reading is at the rate of 250 characters per second. It is 500 microseconds when reading is at 1000 characters per second.

2. The detection of the trailing edge of the sprocket hole halts the transfer of that frame of information to the N-register.

3. The detection of the trailing edge of the sprocket hole also causes the N-register to become ready. The ready condition indicates that N is fully loaded and one frame has been read from paper tape. This condition can be tested by the program and can be seen on the console of the central processor when N REG READY glows green.

It should be noted that the sprocket hole can create a ready condition but it cannot cause a return of the N-register to a not-ready condition. A shift N and A Right (SNA) instruction is required to cause the N-register to become not ready. This SNA instruction should be given as soon as the N-register becomes ready. When this is done, there will be no N-register overlay. Care should be taken after the shift to limit any processing loops (such as character validity and parity checks) to less than the allowable time interval. The HPT instruction must be given to stop paper tape movement.

DATA TRANSFER DURING READING

During a paper tape reading operation, information is transferred without a parity bit from tape to the N-register. An RPT instruction initiates the reading. Information is then transferred from the N-register to the A-register by an SNA instruction. If information read into N is to be immediately typed out or punched, the N- to A-shift is not necessary. The relative bit positions of a character on paper tape are unchanged when the character is read from tape to the N-register, and shifted into the A-register. The information in the A-register is stored by an STA instruction after one, two, or three paper tape characters are transferred from N to A, depending upon the programmer's choice of memory word format. If the shifts from the N-register to the A-register are performed in the normal mode on three successive paper tape characters by SNA 7, SNA 6, and SNA 6, or an SNA 6 three times followed by an SNA 1, the word format from 6-, 7-, or 8-channel tape would be the following

A Register

S	1	2 → 7	8 → 13	14 → 19
X	0	3rd Tape Character	2nd Tape Character	1st Tape Character

Information cannot be transferred into the sign position of the A-register by use of an SNA instruction. Unless the A-register was cleared before its use, the sign remains unchanged from its previous use. When three paper tape characters are positioned in A(2-19) as illustrated, a zero automatically enters bit position 1 at the time of the last shift. The format of a word which has only one paper tape character is most often as follows (the shift from the N to the A register in this case is SNA 19).

	S	1 … 13	14 … 19
A Register	x	0 … 0	Tape Character

Since information transfer from paper tape to the N-register differs according to the code level used, each tape format is described and illustrated and its special characteristics listed (except for 5-level code, which is described separately).

Summary of 6-Level Code Reading

In 6-level code reading:

1. All six information channels from paper tape enter the N-register as shown in Figure 4.
2. There are no illegal code combinations.
3. Six zeros are read into the N-register when a sprocket hole of a leader or trailer is sensed.
4. There is no parity check.
5. There is no delete code.
6. The highest number which can be read is octal 77.

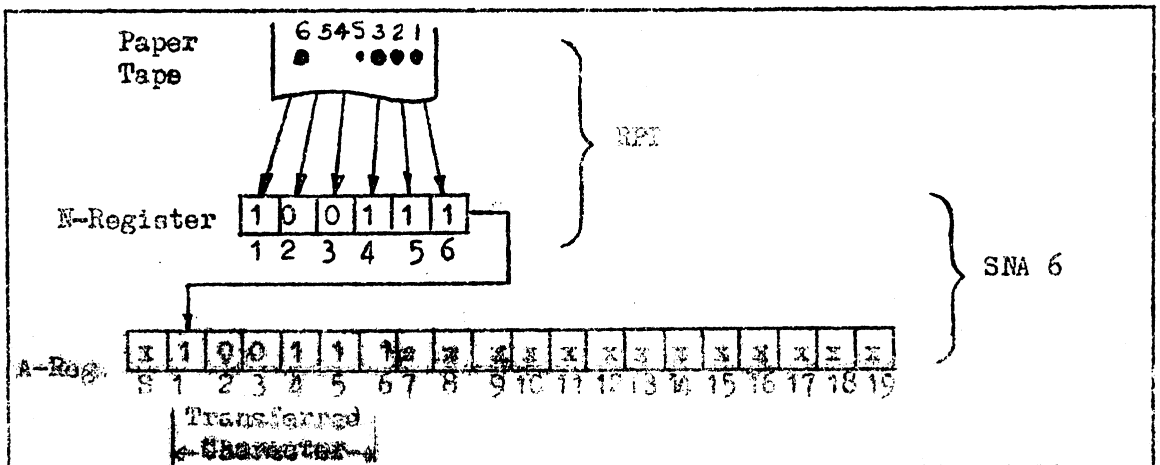


Figure 4 - Reading 6-Level Paper Tape

Summary of 7-Level Code Reading

The reading of 7-level code may be summarized as follows:

1. In reading 7-level code in the normal mode, channel five of the paper tape is not read into the N-register. The presence or absence of the parity bit (P) is sensed by the control logic without requiring the information from channel 5 to be transferred. Information flow from paper tape to the six positions of the N-register is illustrated in Figure 5.
2. The paper tape reader ignores the leader and trailer ends of the tape (when only sprocket holes pass the read station). No information is transferred to the N-register.
3. A frame of paper tape having only a parity punch is read into the N-register as all zeros.
4. When all seven channels are punched in a frame of paper tape, the normal mode of reading sends no information to the N-register. This all-1's configuration on tape is used as a delete code.

5. The highest number which can be read in the normal mode is octal 76.
6. Figure 5 illustrates the manner in which information is read from paper tape into the N-register and shifted from the N-register to the A-register.

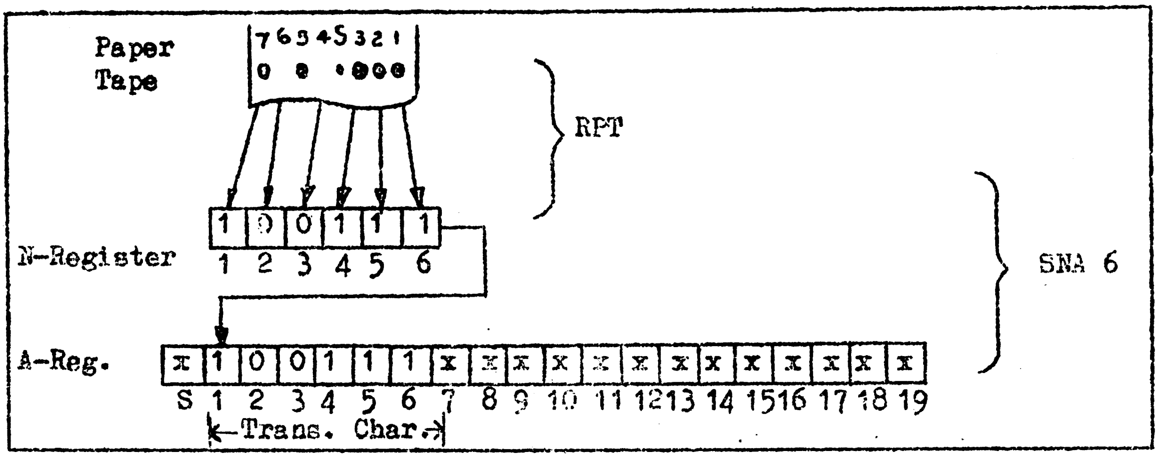


Figure 5 - Reading 7-Level Paper Tape

Summary of 8-Level Code Reading

The reading of 8-level code may be summarised as follows:

1. With few exceptions, 8-level code is read in the same way that 7-level code is read. Channel 5 on tape contains the parity bit. The transfer of information in the normal mode is the same as is illustrated in Figure 5 with one exception. The exception is the special character ccontrol which senses a hole punched only in channel 8 and causes six 1-bits to be placed in the N-register. Figure 6 illustrates this special character transfer. No parity bit is involved in the special character.
2. All code combinations which contain an 8-channel punch plus any other channel punch are considered invalid. Invalid codes are not transmitted to the N-register.
3. The paper tape reader ignores the leader and trailer ends of the tape.
4. A frame of paper tape having only a parity punch is read into the N-register as all zeros.
5. When all seven channels are punched in a frame of paper tape, no information is sent to the N-register during the normal mode of reading. This all-1's configuration on tape is used as a delete code.
6. The highest number which can be read in the normal mode is octal 77.

DATA TRANSFER DURING PUNCHING

During a paper tape punching operation, characters must first be positioned in the A-register. One character at a time is transferred from the A-register to the N-register by an SAN instruction and from the N-register to paper tape by a WPT instruction. With one exception, the relative bit positions of a character in the A-register are unchanged when the character is shifted from the A-register to the N-register and transferred from the N-register to paper tape. The exception is that a parity bit is added as necessary to cause an odd number of punches when information is transferred from the N-register in 7- and 8-level codes.

The sign bit in the A-register does not shift and does not change as characters are shifted out of A. Vacated positions in A are filled with 0-bits if the sign is positive and with 1-bits if the sign is negative. If the A-register contains three characters right-justified, a normal mode transfer to the N-register is in the following order:

	S	1	2 — 7	8 — 13	14 — 19
A-Register	X	X	3rd Character	2nd Character	1st Character

Assuming that the sign is positive and the bit in position 1 is unknown, the A-register shown above would contain the following configuration after an SAN 6 instruction:

	S	1 — 7	8 — 13	14 — 19
A-Register	0	0 0 0 0 0 0 X	3rd Character	2nd Character

Notice that the bit originally in position 1 remains unchanged as it shifts. Since information transfer differs according to the code level used, each tape format is described and illustrated separately (except for 5-level code, which is described separately).

<u>Summary of 6-Level Code Punching</u>

In 6-level code punching:

1. Six channels are punched in paper tape as is shown in Figure 6.
2. The paper tape punch feeds tape to create a leader or a trailer (sprocket hole only) when the N-register contains 111111.
3. There is no parity check.
4. There is no delete code.
5. The highest number which can be punched is octal 76.

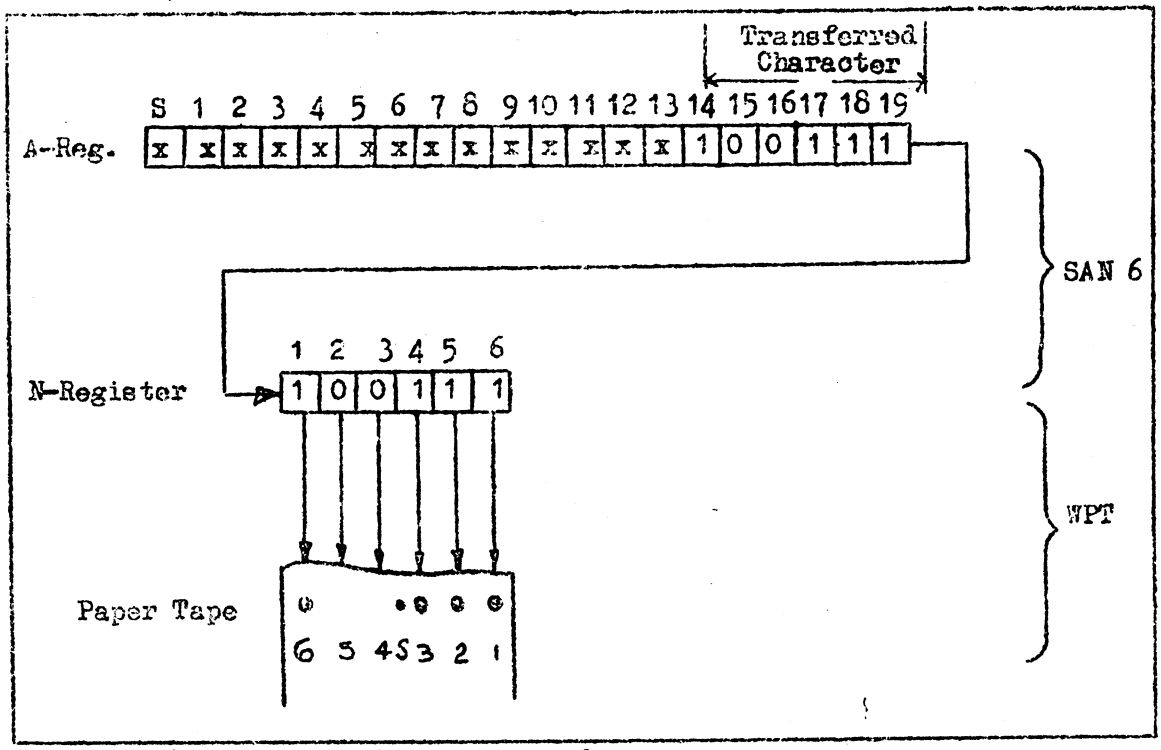


Figure 6 - Punching 6-Level Paper Tape

Summary of 7-Level Code Punching

The punching of 7-level code may be summarized as follows:

1. The normal mode of punching causes a parity punch to be added in channel 5 each time a parity check shows that the N-register contains an even number of 1-bits. This makes the total number of holes in a paper tape frame odd. The use of channel 5 for parity prevents its use for data, causing channel 6 to receive data from N2 and channel 7 to receive data from N1. This is illustrated in Figure 7.
2. The configuration of 111111 in the N-register causes a leader or a trailer (sprocket hole only) to be punched.
3. A zero in the normal mode is punched as a parity punch only.
4. The highest number which can be punched in the normal mode is octal 76.
5. Figure 7 illustrates the manner in which information is shifted from the A-register to the N-register and punched in paper tape.

Summary of 8-Level Code Punching

The punching of 8-level code may be summarized as follows:

1. With few exceptions, 8-level code is punched in the same way that 7-level code is punched. The parity bit is punched in channel 5. Transfer of information in the normal mode is the same as is illustrated in Figure 7 with one exception. The exception is that a character

consisting of 1-bits (111111) sent to the N-register is punched as a channel 8 punch only. Figure 8 illustrates this special character transfer. No parity bit is involved in the transfer.

2. A zero is punched in the normal mode as a parity punch only.

3. The highest number which can be punched in the normal mode is a single punch in channel 8 which is octal 100.

4. It is not possible to program the punching of a leader or a trailer (sprocket hole only).

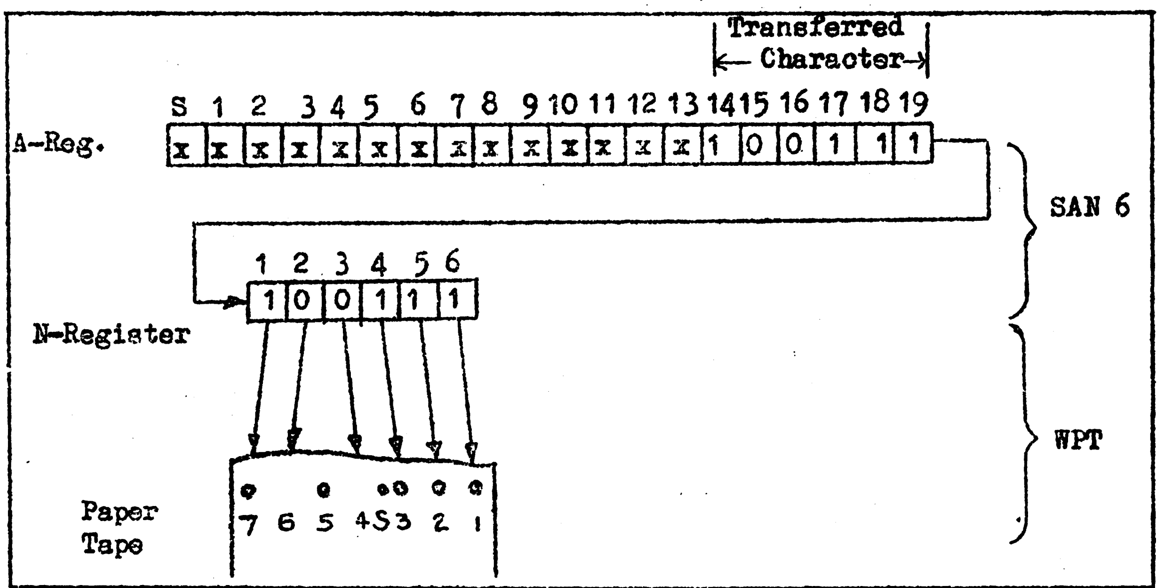


Figure 7 - Punching 7-Level Paper Tape

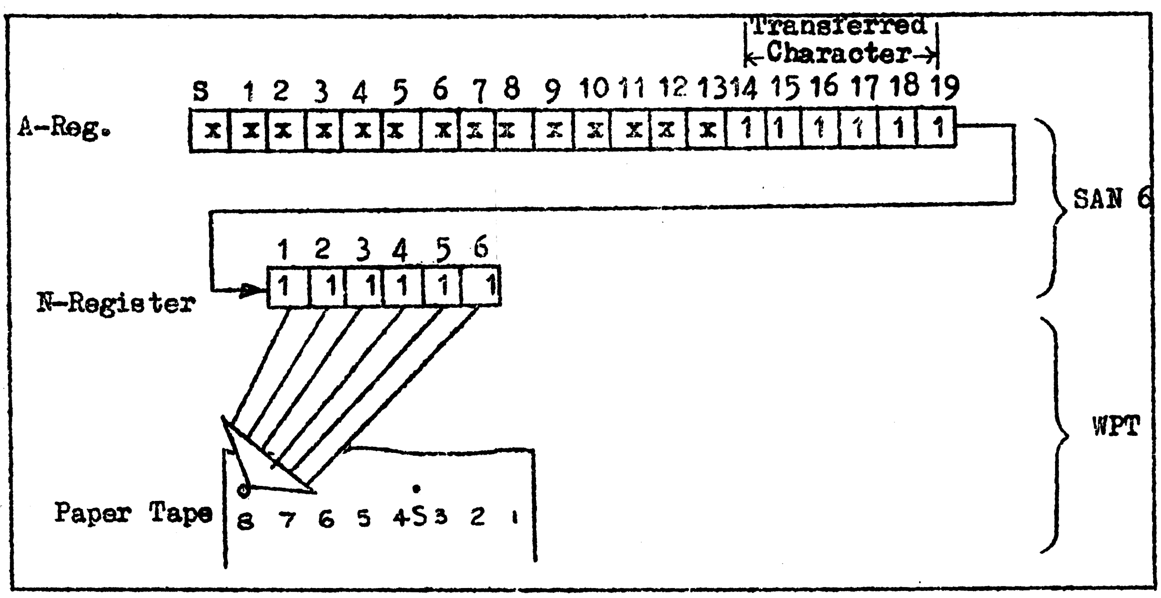


Figure 8 - Special Character Punching 8-Level Code

FIVE-CHANNEL PAPER TAPE

The 5-channel paper tape code is the shortest of the paper tape codes because each punched configuration may have two different meanings, depending upon whether the machine has been shifted into upper case or lower case by a preceding code. To designate upper or lower case in a program, the programmer must use the "letter shift" code (octal 36) to designate upper case, and the "figure shift" code (octal 33) to designate lower case. Just as with the Teletype or typewriter, a shift to upper case means that every character following the shift is upper case until a lower case shift is given. Likewise, everything following a lower case shift is lower case until the upper case shift is given. Failing to give the shifts at the proper time causes errors in the interpretation of the data punched or read.

5-Channel Code

The code as used by the University of Queensland Computer Centre is shown in Figure 10. All the digits and the special characters +, - and . have an odd number of one-bits in the representation in order to aid checking by program for numeric (data) input. There is no parity checking on 5-channel tape.

Conversion of BCD to 5-Channel Tape Output

If BCD information in memory is to be punched on 5-channel tape in the 5-channel code, there must be a code conversion. Figure 10 contains the output code which represents in octal the information which must be in the N-register in binary to punch the specified character. The following example illustrates the use of the Figure 10.

Problem: If the numeral 3 is to be punched on 5-channel tape, what configuration must be sent to the N-register to punch the 3?

Solution: The first column for lower case codes in Figure 10 contains the number 3. Opposite the 3 in the next column to the right is the octal representation for the BCD emmory code for 3. This is 03, which represents a binary 000011 in memory. In the next column to the right is the octal representation for the 5-level code. This code is 23, which represents 10011 in the N-register. It must be remembered that only N2 through N5 are used. In order to punch 03, the memory configuration 000011 must be converted to 10011 prior to sending it to the N-register, and the previous shift character must have been a figure shift. This conversion is normally done by the routine WPT.

CONVERSION OF 5-CHANNEL TAPE INPUT TO BCD

If information from 5-channel tape is to be used in memory along with other memory information (information not read from paper tape), tape information must be converted to the configuration of memory BCD characters. Likewise, if information from 5-channel tape is to be used in some other form of output, for example as printed output, it must also be in the configuration of memory BCD characters. Figure 10 lists the codes used when reading tape.

An example of the use of the table follows:

Problem: When the letter S is read from paper tape into memory, what must the memory configuration be to print the letter S on the high-speed printer?

Solution: It is first seen from Figure 10 that the letter S is in the "letter shift" half of the table and must have been preceded by a letter shift character. The fourth column of the table shows that the octal representation of the letter S (opposite S in the first column) is 23. This means that 10011 is sent to the N-register when the letter S is read from paper tape. The third column of the table indicates that octal 62 represents the 6-bit binary code required in memory to represent the letter S. The memory configuration for the character must therefore be 110010 to print the letter S. This conversion is normally done by the RPT S/R.

DATA TRANSFER-PUNCHING

The first step in punching paper tape is to position characters in the A-register. The following illustrates the A-register, which has three characters right-justified and labeled in the order in which the characters will be punched.

<table>
<tr><td></td><td>S</td><td>1</td><td>2</td><td>3 ←→ 7</td><td>8</td><td>9 ←→ 13</td><td>14</td><td>15 ←→ 19</td></tr>
<tr><td>A-Register</td><td>x</td><td>x</td><td>0</td><td>Third Character</td><td>0</td><td>Second Character</td><td>0</td><td>First Character</td></tr>
</table>

Notice that bit positions 2, 8, and 14 contain zeros. Characters are kept in 6-bit configuration to facilitate conversions to BCD memory code or other codes which require 6 bits per character. Actually, no confusion would result if 1-bits were in positions 2, 8, and 14 of the A-register. Information from these positions transfers from the A-register to the N-register but does not transfer from N1 to paper tape. The sign bit in the A-register does not shift and does not change as characters are shifted out of A. Vacated positions in A are filled with 0-bits if the sign is positive and with 1-bits if the sign is negative. The following is what the A-register just illustrated would contain after the execution of an SAN 6 instruction, providing the sign of A was negative.

	S	1 2 ... 7	8	9 ... 13	14	15 ... 19
A-Register	1	1 1 1 1 1 1 x	0	Third Character	0	Second Character

The bit which was originally in position 1 remains unchanged as it shifts. If the A-register had been cleared to zero before characters were shifted into it, bit position 1 would contain a zero before the execution of SAN 6 and bit position 7 would have a zero after the execution of SAN 6. The transfer of information from the A-register to paper tape via the N-register during punching is illustrated in Figure 11. The transfer to the N-register is made by a Shift A and N Right instruction. Transfer from the N-register to paper tape is made by a Write Paper Tape instruction.

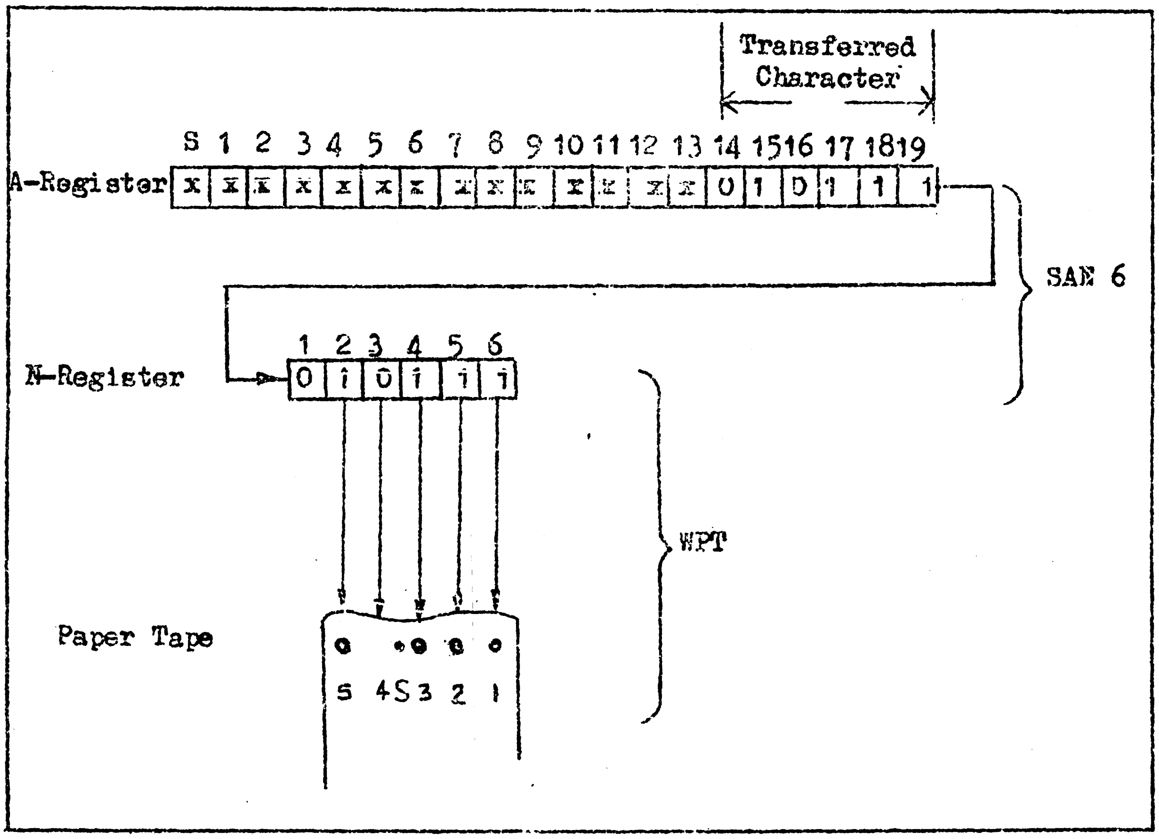


Figure 11 - Punching 5-Level Paper Tape

The following list summarizes information which applies especially to punching 5-level paper tape code:

1. The paper tape punch punches only sprocket holes to create a leader or a trailer when the N-register contains 000000 at the time WPT is executed.

2. No parity bit is on paper tape and no parity check is made.

3. Any configuration in N2 - N6 is punched by execution of WPT (there are no invalid codes).

4. The highest number which can be punched is octal 37.

5. A letter shift or figure shift code must be used to differentiate between upper and lower case codes.

DATA TRANSFER-READING

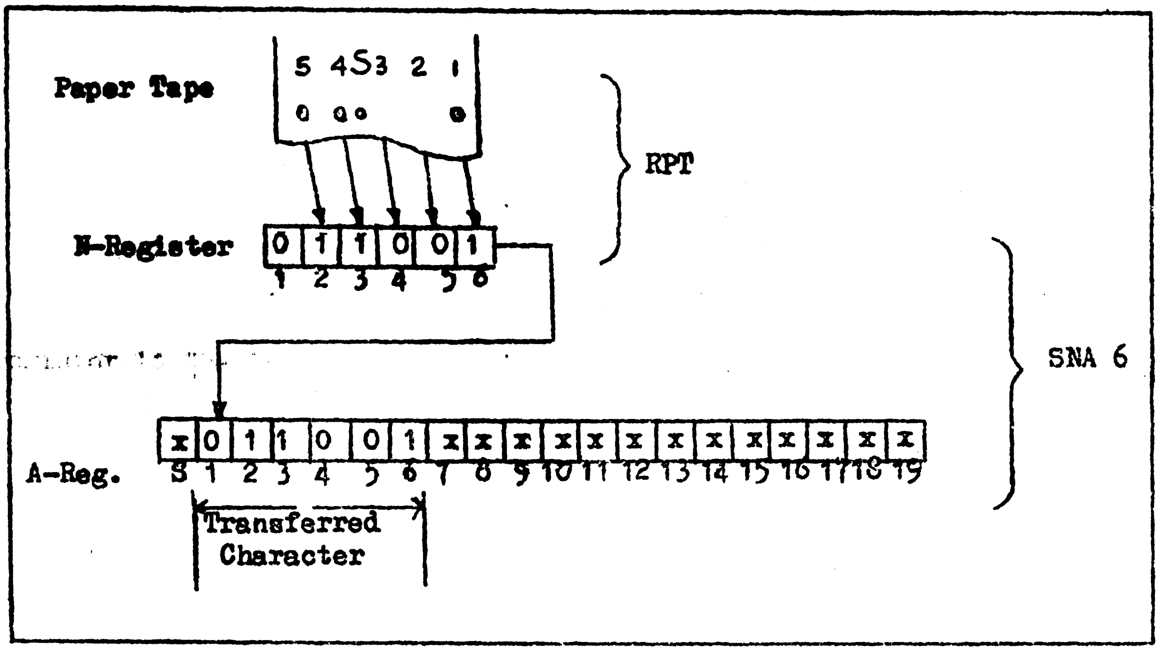
When five bits of information are transferred into the N-register from a paper tape character, a zero automatically fills the first position of the register. Three tape characters can then be placed in the A-register in the following configuration by use of the successive shift instructions SNA 7, SNA 6, and SNA 6. Each time, all six bits including the zero shift from N. This configuration facilitates conversion of 5-bit tape codes to 6-bit BCD characters.

	S	1	2	3 ←→ 7	8	9 ←→ 13	14	15 ←→ 19
A-Register	x	0	0	3rd Tape Character	0	2nd Tape Character	0	1st Tape Character

The SNA instruction does not shift information into the sign position of the A-register. Unless the A-register was cleared to zero before its used, the sign remains unchanged from its previous use. The format of a word which has only one paper tape character placed in the A-register by an SNA 19 instruction is as follows:

	S	1 ←→ 13	14	←→ 19
A-Register	x	0 ←→ 0	0	Tape Character

The transfer of information from paper tape to the A-register via the N-register during the reading of 5-level tape code is illustrated in Figure 12. Transfer to the N-register is initiated by a Read Paper Tape instruction. Transfer from the N-register to the A-register is made by a Shift N and A Right instruction.



The following list summarizes information which applies especially to reading 5-level paper tape:

1. The reader sends 000000 to the N-register when only a sprocket hole (as in the leader or trailer) is sensed.

2. No parity check is made and no parity bit is on tape.

3. Every configuration on paper tape is considered valid and is transferred to the N-register.

4. The highest number which can be read is octal 37.

5. A letter shift or figure shift must be used to differentiate between upper and lower case codes.

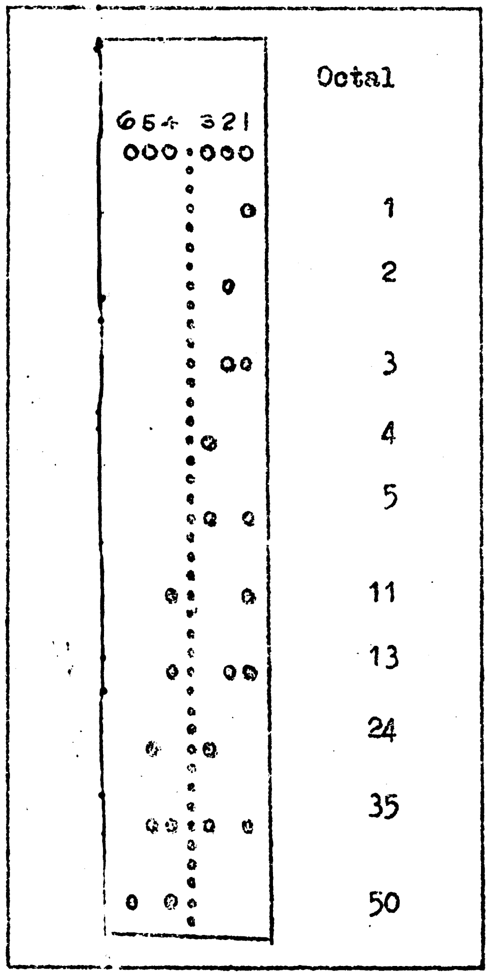


Figure 1. Paper Tape Characters Read in Octal

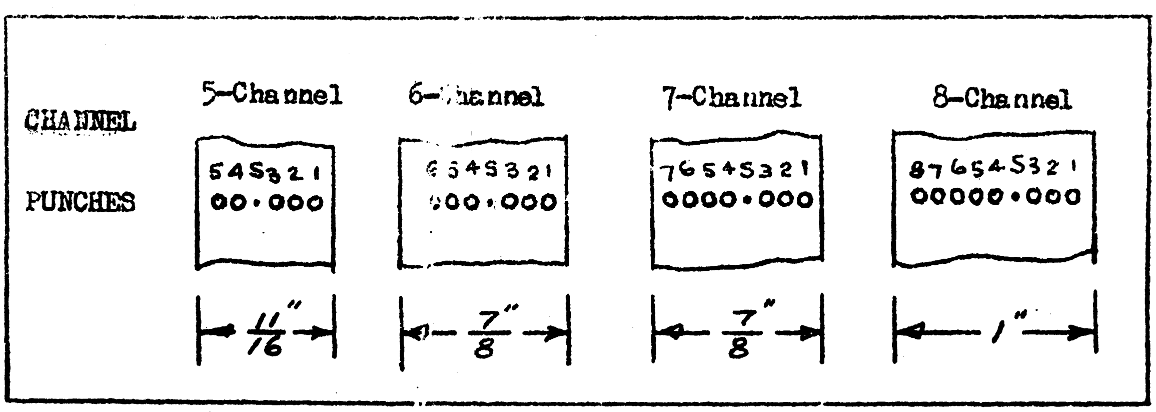


Figure 2. Paper Tape Formats

CHARACTER	B.C.D. MEMORY (OCTAL)	5-CHANNEL PAPER TAPE (OCTAL) FIGURE SHIFT	LETTER SHIFT
Figures:			
0	00	20	
1	01	01	
2	02	02	
3	03	23	
4	04	04	
5	05	25	
6	06	26	
7	07	07	
8	10	10	
9	11	31	
10			
11			
Letters:			
A	21		01
B	22		02
C	23		03
D	24		04
E	25		05
F	26		06
G	27		07
H	30		10
I	31		11
J	41		12
K	42		13
L	43		14
M	44		15
N	45		16
O	46		17
P	47		20
Q	50		21
R	51		22
S	62		23
T	63		24
U	64		25
V	65		26
W	66		27
X	67		30
Y	70		31
Z	71		32

Figure 10. University of Queensland
5-Channel Paper Tape Code

SPECIAL CHARACTERS:	B.C.D. MEMORY (OCTAL)	PAPER TAPE 5-CHANNEL FIGURE SHIFT	LETTER SHIFT
SPACE	60	34	34
-	40	13	
+	20	32	
/	61	27	
*	54	03	
.	33	15	
,	73	17	
=	13	12	
(	74	05	
)	34	06	
~	15	21	
#	16	11	
£	53	22	
'	14	24	
:		16	
▭		30	
Δ		14	
@	14		
%	17		
CONTROL CHARACTERS:			
FIGURES		33	33
LETTERS		36	36
C.R./L.F.	37	35	35
BLANK/DELAY	77	00	00
ERASE		37	37
PRINT RED	72		
PRINT BLACK	75		
TAB	76		
C.R.	37		