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MASTER

PUNCHED-TAPE CODE AND FORMAT FOR NUMERICALLY CONTROLLED MACHINES

R. V. Miskell

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT Contract W-7405 eng 26**

UNION CARBIDE

OAK RIDGE Y-12 PLANT
P. O. Box Y
OAK RIDGE, TENNESSEE 37830

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R. V. Miskell

Oak Ridge, Tennessee

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ABSTRACT

A clarification of the newer punched-tape codes and formats for numerically controlled machines is needed. The description of the systems will assist personnel who are responsible for the procurement and operation of numerically controlled machines.

CONTENTS

SUMMARY

This report is concerned with a description of the punched-tape code and format used on the newer numerical control systems. A discussion of the different codes, formats, and data is included.

INTRODUCTION

There is a wide variety of numerical control systems found in industry today. The terminology or "jargon" used to describe the tape codes and formats used on the punched tape for these controls is not uniform. An understanding of this terminology facilitates communications between the purchaser of numerically controlled equipment and supplier, the part programmer and shop foreman, and the part programmer and computer programmer. This report is meant to serve as a handy educational assist in the numerical control community.

PUNCHED-TAPE CODE AND FORMAT

INTRODUCTION

"Tape coding" is defined as the predetermined arrangement of possible locations of holes in the tape and the rules for interpreting the various possible patterns. "Tape format" is defined as the physical arrangement of possible locations of holes and the general order in which information appears in the tape.

The Electronic Industries Association (EIA), in a group of industry specifications issued from 1959 through 1963, set the industry standard on tape coding and format for numerically controlled machines. These specifications–RS-244, "Character Codes for Numerical Machine Control Perforated Tape"; RS-273, "Interchangeable Perforated Tape Variable Block Format for Positioning and Straight-Cut Numerically Controlled Machines"; RS-274, "Interchangeable Perforated Tape Variable Block Format for Contouring and Contouring/Positioning Numerically Controlled Machines"; and RS-326, "Interchangeable Perforated Tape Fixed Block Format for Positioning and Straight-Cut Numerically Controlled Machines"–are very important documents for both users and builders of numerical control equipment. The EIA TR-31 committee, in view of technological advances in the state of the art, has periodically updated the aforementioned standards and initiated new specifications.

TAPE CODING

A quick review of the binary system will facilitate an understanding of tape coding. Any number, N, in a system of base, b, can be expressed as follows:

$$(N)_b = P_n b^n + P_{n-1} b^{n-1} + \ldots P_o b^o + P_{-1} b^{-1} + \ldots + P_{-m} b^{-m}, \text{ or}$$

$$(N)_b = \sum_{i=m}^{n} P_i b^i,$$

where "b" is an integer greater than 1 and $0 \leq P_i \leq (b-1)$.

The binary system is a base-two number system, hence:

$$(N)_2 = \sum_{i=-m}^{n} P_i 2^i, \; 0 \le P_i \le 1.$$

Since, in this study, the primary interest is in the integral part,

$$(N)_2 = \sum_{i=0}^{n} P_i 2^i, \; 0 \le P_i \le 1.$$

As examples:

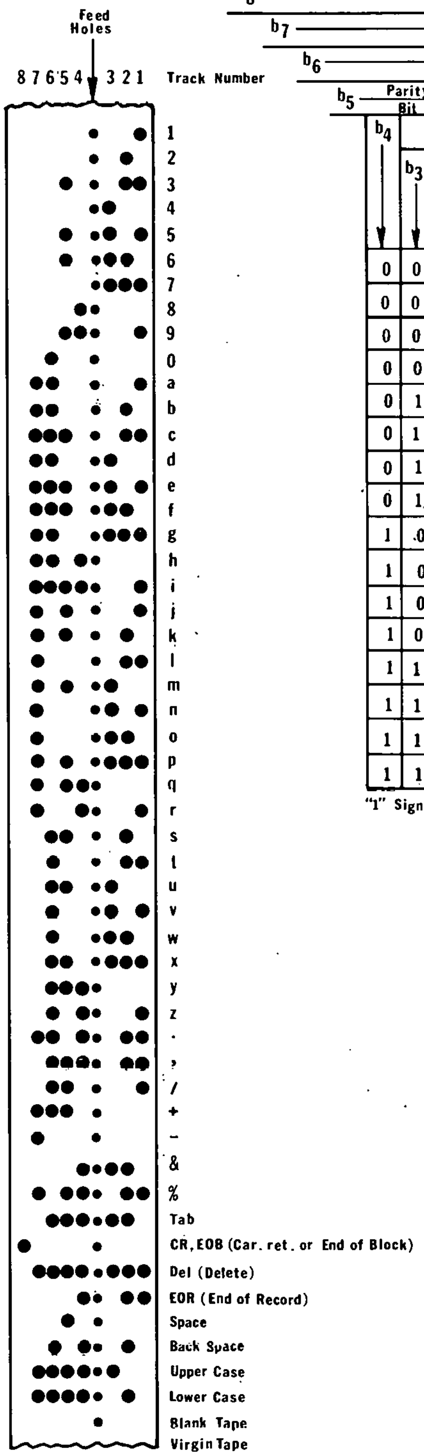
$$(110)_2 = 1 \cdot 2^2 + 1 \cdot 2^1 + 0 \cdot 2^0 = 4 + 2 + 0 = 6, \text{ and}$$

$$(1001)_2 = 1 \cdot 2^3 + 0 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 = 8 + 0 + 0 + 1 = 9.$$

It is necessary to use at least four binary digits to represent all 10 decimal digits. The most popular four-bit code is the 8,4,2,1 code. This code is a weighted code because the decimal digits are determined from the coefficients 8,4,2,1 which are the code weights. The number "379" is represented by 0011, 0111, and 1001 in the 8,4,2,1 code. Other weighted codes are 3331, 5221, and 6321. These weighted codes are all commonly designated as binary coded decimal (BCD) codes.

The universally accepted punched tape for numerical control has eight tracks or channels (see Figure 1). Four of these tracks (one through four) are used for the BCD digits; Track five is used for parity; Tracks six and seven are combined with Tracks one through four to attain alphabetic and special characters; Track eight is a special character, carriage return, or end of block. Figure 1 pictorially explains the code.

During the time that EIA RS-244 was being written and issued, an American Standard Code for Information Interchange (ASCII) was being formed under the auspices of the Business Equipment Manufacturers Association (BEMA). This code was to be compatible with both computers and transmission equipment and meant to eliminate many black-box code converters that were appearing on interfaces. This ASCII code was released almost three years after RS-244. EIA felt that the ASCII code would be used in numerical control applications and, accordingly, issued a recent standard: RS-358, "ASCII Subset for Numerical Machine Control Perforated Tape". Figure 2 depicts this ASCII subset for numerical control.

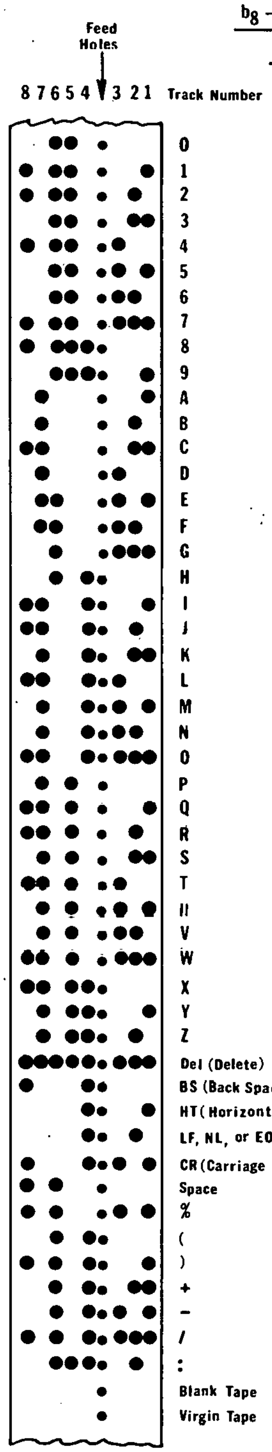


Subscripts Refer to Track Numbers

b_4	b_3	b_2	b_1	b_8=0 b_7=0 b_6=0	b_8=0 b_7=0 b_6=1	b_8=0 b_7=1 b_6=0	b_8=0 b_7=1 b_6=1	b_8=1 b_7=0 b_6=0	b_8=1 b_7=0 b_6=1	b_8=1 b_7=1 b_6=0	b_8=1 b_7=1 b_6=1
				b_5 Parity Bit							
0	0	0	0	Space	0	–	+	CR EOB			
0	0	0	1	1	/	j	a				
0	0	1	0	2	s	k	b				
0	0	1	1	3	t	l	c				
0	1	0	0	4	u	m	d				
0	1	0	1	5	v	n	e				
0	1	1	0	6	w	o	f				
0	1	1	1	7	x	p	g				
1	0	0	0	8	y	q	h				
1	0	0	1	9	z	r	i				
1	0	1	0		BS		LC				
1	0	1	1	EOR	,	%	.				
1	1	0	0				UC				
1	1	0	1								
1	1	1	0	&	Tab						
1	1	1	1				Del				

"1" Signifies a hole, "0" Signifies no hole

Figure 1. CODE FOR NUMERICALLY CONTROLLED MACHINES' PERFORATED TAPE.



Subscripts Refer to Track Numbers

b_4	b_3	b_2	b_1	Row \ Col								
				b_8								
				b_7	0	0	0	0	1	1	1	1
				b_6	0	0	1	1	0	0	1	1
				b_5	0	1	0	1	0	1	0	1
					0	1	2	3	4	5	6	7
0	0	0	0	0	Blank Tape		Space	0		P		
0	0	0	1	1				1	A	Q		
0	0	1	0	2				2	B	R		
0	0	1	1	3				3	C	S		
0	1	0	0	4				4	D	T		
0	1	0	1	5			%	5	E	U		
0	1	1	0	6				6	F	V		
0	1	1	1	7				7	G	W		
1	0	0	0	8	BS		(	8	H	X		
1	0	0	1	9	HT		)	9	I	Y		
1	0	1	0	10	NL, LF or EOB			:	J	Z		
1	0	1	1	11			+		K			
1	1	0	0	12	CR				L			
1	1	0	1	13			–		M			
1	1	1	0	14					N			
1	1	1	1	15			/		O			Del

"1" Signifies a hole, "0" Signifies no hole

Figure 2. ASCII SUBSET CODE FOR NUMERICALLY CONTROLLED MACHINES' PERFORATED TAPE.

TAPE FORMAT

The vast majority of numerically controlled machines, both positioning and continuous path, employ "word address" data. This is to say that all the words are addressed. As an example, the numerical control input word (word on punched tape), x+3500, has an address, x, a positive sign, and a value, 3500. Since there are not any decimal points on the tape, the value of the x word could be 3500., 350.0, 3.50, or any other location of the decimal. The manner in which the decimal is located will be discussed later. One or a group of words make up a block of information on the punched tape. As an example, the block: n025 g01 x-03216 y+00782 f415 m01* is made up of six words: n, g, x, y, f, and m. The asterisk signifies the end of a block. This function is denoted by a punch in Track eight on the punched tape when employing RS-244 coding, and punches in Tracks one, three, four, and eight when employing RS-358 coding. The function of each of the words in a block of information is specified by the EIA standards on tape format—RS-273 and RS-274.

In the previous block, the "n" word is the block number and the "g" word is a preparatory function which sets the mode of operation of the control system. The "x" and "y" words are departure words; that is, they indicate the distance the machine should move. The "f" word is the feedrate word; that is, it specifies the rate at which the machine should move. The "m" word is a miscellaneous function and is used to activate functions like turning the spindle or coolant on or off, stopping the machine, or rewinding the punched tape.

As was mentioned before, there are not any decimal points in the tape; and, hence, the departure word "x02500" is ambiguous until it is known where the decimal point is located. The "format detail" of the punched tape specifies the location of the decimal point and the number of digits that comprise each word. An example of a format detail is: n3 g2 x+14 y+14 f21 m2*. The interpretation of this format detail is as follows: The sequence number, "n" word, has three digits; the preparatory function, "g" word, has two digits; the "x" and "y" departure words use + and - signs, and there is one digit to the left of the decimal point and four digits to the right of the decimal point. The feedrate "f" word has two digits to the left of the decimal point and one digit to the right of the decimal point. The "n", "g", and "m" words are always integers. The values of the "x", "y", and "f" words in the aforementioned tape block example would be: -.3216, .0782, and 41.5, respectively.

ABSOLUTE AND INCREMENTAL DATA

There are two basic types of departure data or dimension words—absolute and incremental. Most positioning systems in the field use absolute data, while continuous-path machines usually use incremental data.

With absolute data there is a fixed origin; with incremental data the origin essentially moves with the tool. The differences can best be explained by a simple example. Suppose, in Figure 3, there is a desire to move from A to B, then B to C, then C to D, and so forth with the final movement from I to A. Let it further be assumed that there is a +13 format for departure words; then, for absolute data, the departure commands are:

X+0000	Y-3000	(B)
X+2000	Y-3000	(C)
X+2000	Y+0000	(D)
X+2000	Y+1500	(E)
X+0000	Y+1500	(F)
X-2000	Y+1500	(G)
X-2000	Y+0000	(H)
X-2000	Y-3000	(I)
X+0000	Y+0000	(A)

Since plus signs are usually assumed and repeated dimensions are usually not necessary, the absolute data could be reduced to:

X 0000	Y-3000	(B)
X 2000		(C)
	Y 0000	(D)
	Y 1500	(E)
X 0000		(F)
X-2000		(G)
	Y 0000	(H)
	Y-3000	(I)
X 0000	Y 0000	(A)

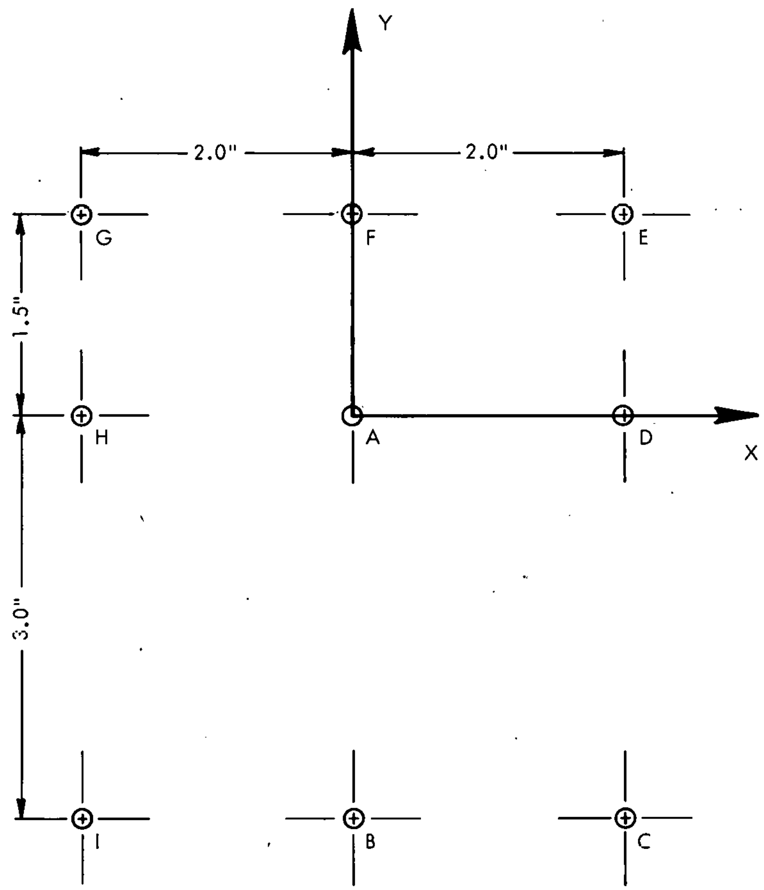


Figure 3. REPRESENTATIVE HOLE PATTERN.

For incremental data, the departure commands are:

X+0000	Y-3000	(B)
X+2000	Y+0000	(C)
X+0000	Y+3000	(D)
X+0000	Y+1500	(E)
X-2000	Y+0000	(F)
X-2000	Y+0000	(G)
X 0000	Y-1500	(H)
X-0000	Y-3000	(I)
X-2000	Y+3000	(A)

Again, plus signs are usually assumed and zero departures can be omitted; therefore, the departure commands for incremental data would reduce to:

	Y-3000	(B)
X-2000		(C)
	Y 3000	(D)
	Y 1500	(E)
X-2000		(F)
X-2000		(G)
	Y-1500	(H)
	Y-3000	(I)
X-2000	Y 3000	(A)

The input circuitry of some control systems is such that leading or trailing zeros can be deleted. For example, a control system that does not require trailing zeros could have the departure word: x-0500, with the +13 format input as x-05. Likewise, a control that does not require leading zeros could have the same departure entered as x-500. Many controls can presently delete either leading or trailing zeros. Since the tape block size can vary because of deleted words and deleted leadings or trailing zeros, this type of data is designated as "variable block".

The format detail previously discussed did not specify whether the departure data were incremental or absolute, nor did it indicate whether the control was a positioning or contouring control. The "format classification shorthand" specifies these data.

An example of a classification shorthand is: c23.313.22. An explanation of this classification shorthand is given in Figure 4 and describes the tape block previously mentioned (Page 11). RS-273 and RS-274 should be consulted for an in-depth description of format detail and classification shorthand.

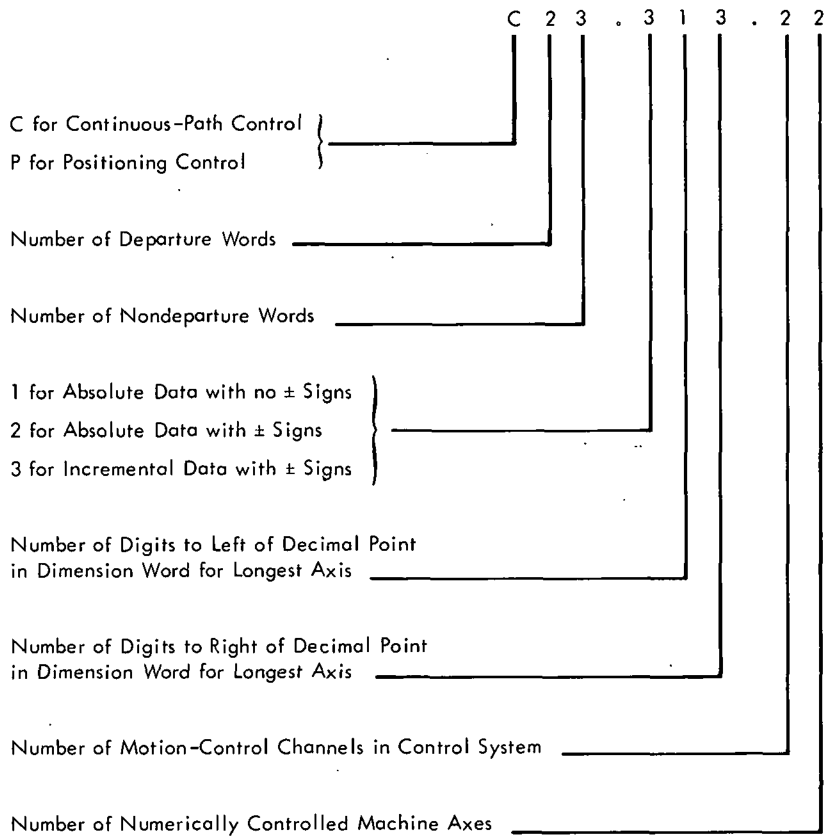


Figure 4. EXAMPLE OF CLASSIFICATION SHORTHAND.