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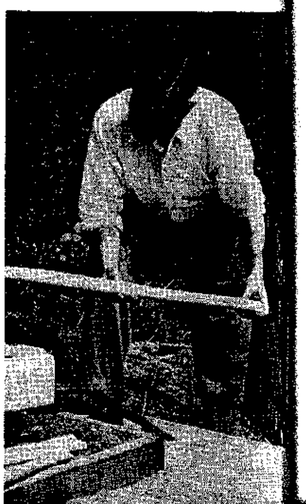

Code patterns in telephone switching and accounting systems

J. W. DEHN
Switching Systems Development

In telephone switching and accounting systems certain information regarding each call must be transmitted and recorded quickly and accurately. In many cases, moreover, the same information must be transmitted and recorded many times. Most of this information is in the form of decimal numbers, of which the component parts or digits may have any of 10 values. The telephone number CH3-1074, for example, is equivalent to the decimal number 2431074, since as a glance at a standard dial will show, C is one of the three letters that is represented by 2, and H, one of the three letters represented by 4. Much other information regarding each call is also represented by decimal numbers. The physical location of each line in the switching equipment, for example, the trunk and other parts of the switching system used on the call, and the rate of charge, are all represented by decimal numbers. It is obvious, therefore, that the transmitting and recording of decimal numbers by electrical and mechanical means is very important in telephone systems.

In transmitting decimal numbers from place to place, each of the ten possible values of a digit must be represented by a unique electrical or mechanical condition. Both the mechanical and electrical representations of a digit are used in the familiar dial. The number of degrees in the arc through which the dial is mechanically rotated for a specific digit is proportional to the value of the digit—"one" being the smallest arc, and "zero" being the largest. The arc representing 0 is ten times that of the arc representing "one". The values "two" to "nine" are represented by arcs of intermediate value. When the dial is released by the calling subscriber, it produces, on its return to its normal position, a number of electrical impulses corresponding to the length of the arc through which it rotates, one impulse for the value "one", two impulses for "two", and so forth, with ten impulses for "zero".

In the central office, electrical and mechanical devices respond to these impulses and take one of ten positions dependent upon the value of the digit dialed. Thus a decimal number, such as 2431074, is transmitted from a subscriber station and recorded in the central office by means of a simple code, each digital value being represented by a discrete dial arc, a number of impulses, and a position of the recording device.

TABLE I—A FOUR-ELEMENT CODE USED FOR SOME PURPOSES IN THE BELL SYSTEM TO REPRESENT DECIMAL DIGITS. THE ELEMENTS OF THE CODE USED TO REPRESENT A DIGIT ARE INDICATED BY X'S: ELEMENTS NOT USED ARE INDICATED BY —

Decimal Digit Represented	Code Elements 1	2	4	5
1	X	—	—	—
2	—	X	—	—
3	X	X	—	—
4	—	—	X	—
5	—	—	—	X
6	X	—	—	X
7	—	X	—	X
8	X	X	—	X
9	—	—	X	X
0	—	—	—	—

This simple decimal code is frequently used to pass a number from place to place within a central office by providing ten conductors per digit between the two places and closing current to one and only one of these conductors. It is also used to transmit all or part of a decimal number to a distant office by means of electrical impulses similar to those generated by a dial.

Where transmitting and receiving devices must be simple, as in station equipment, this code is suitable. There are many cases, however, where more complex codes are used for purposes of economy, accuracy, or speed. The decimal code has ten elements, one for each of the ten values to be indicated. It is possible, however, to represent ten values with a code of fewer than ten elements by using combinations of two or more of the elements to indicate the ten values. A code having four elements, where a single element or a combination of two, three, or four elements are used, can represent as many as sixteen values, and, of course, ten of these sixteen can be used to represent a decimal digit. One practical code of this nature has its four elements designated 1, 2, 4 and 5, and the ten digital values are represented in Table I.

Table II—Another Four-element Code Used in the Bell System

Decimal Digit Represented	Code Elements 1	2	4	8
1	X	–	–	–
2	–	X	–	–
3	X	X	–	–
4	–	–	X	–
5	X	–	X	–
6	–	X	X	–
7	X	X	X	–
8	–	–	–	X
9	X	–	–	X
0	–	–	–	–

It will be noticed that the sum of the elements equals the value of the digit. Another four-element code, shown in Table II, is also used, and again the sum of the elements equals the value of the digit.

Each of these two codes has certain characteristics which are desirable for specific purposes. In panel and crossbar No. 1 systems, for examples, the 1, 2, 4, 5 code is used for all digits except the thousands digit, which uses the 1, 2, 4, 8 code. There is an advantage in using 1, 2, 4, 8 for the thousands digit and 1, 2, 4, 5 for the hundreds digit because this facilitates translation from these two decimal digits to the incoming brush, incoming group, and final brush selections used in the panel system and *vice versa.*

Four-element codes such as the above have been in use in telephone switching systems since about 1914, when the call-indicator systems were installed in New York City for completing calls from the Metropolitan toll office in Walker Street to the various manual "B" switchboards throughout the city. Four impulses or spaces are transmitted for each digit. These impulses (or spaces if the impulse is omitted) are nominally 0.070 second in duration; so that 0.280 second is required for the transmission of each digit. Each of the four impulses or spaces is one element of the code. By suitable receiving equipment the decimal value is reconstructed. The higher average speed of the four-element code, compared with the ten-element code, permits more efficient use of the common control devices.

Table III—In Recent Years a Five-element Code Has Come Into Extensive Use

Decimal Digit Represented	Code Elements 0	1	2	4	7
1	X	X	–	–	–
2	X	–	X	–	–
3	–	X	X	–	–
4	X	–	–	X	–
5	–	X	–	X	–
6	–	–	X	X	–
7	X	–	–	–	X
8	–	X	–	–	X
9	–	–	X	–	X
0	–	–	–	X	X

The four-element code is also used to pass a decimal number from place to place within a central office. This is usually accomplished by providing four conductors for each digit between the two places concerned. This is a substantial reduction over the ten conductors required for the simplest code, and, although wires are not very expensive, the contactors and means for actuating them to establish multi-conductor connections between parts of a system are costly. Each of the four wires and the four devices actuated by them are the four code elements, and are used in the patterns shown.

In 1942, a five-element code came into use in telephone systems. The five elements are given the designation 0, 1, 2, 4, and 7,

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Code Elements			
1	2	4	7
X	—	—	—
—	X	—	—
X	X	—	—
—	—	X	—
X	—	X	—
—	X	X	—
—	—	—	X
X	—	—	X
—	X	—	X
—	—	X	X

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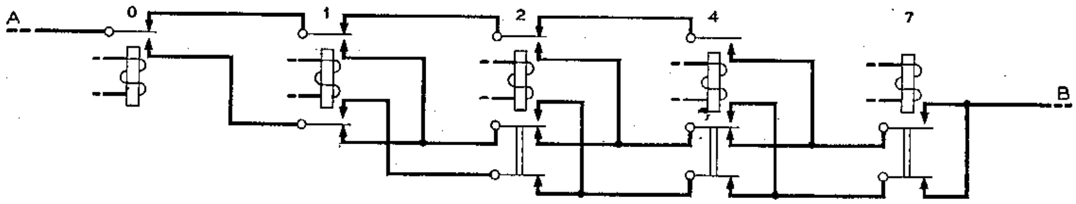

Fig. 1—One form of checking circuit used with the new five-element code.

and each digital value is represented by two of the elements, as given in Table III.

It will be noticed that for the values 1 through 9, the sum of the element designations is equal to the value which the combination represents. There are only ten combinations of five elements taken two at a time, and thus the remaining combination, 4 and 7, must be used for zero.

The principal advantage of this code is that devices can be readily designed to receive decimal numbers in this code, check for errors due to equipment or line faults, and to call attention to the trouble. Systems using the four-element code check intra-office wiring by an indirect method, which is somewhat slower than the direct method used with the five-element code. Inter-office pulsing using the four-element and similar codes is not self-checking. Checking with the five-element code is accomplished by arranging the transmitting or receiving device to demand that exactly two of the code elements are actuated for each digit. A lost element or an added element indicates trouble. Figure 1 shows a commonly used configuration of relay contacts, which assures that exactly two of the five relays are operated. The electrical path from A at the left to B at the right will be closed if any two relays, no more and no less, are operated for the digit. The path is, of course, extended through similar contact configurations for other digits of the decimal number, so that, if an error appears in any digit, circuit action is stopped, and trouble reported.

One use of the five-element code is for transmitting a decimal number from one office to another. Power supplies of five distinct frequencies are available at the originating office for use in combinations of two. The frequencies used and their corresponding code designations are:

0	1	2
700 cycles	900 cycles	1100 cycles
4	7	
1300 cycles	1500 cycles	

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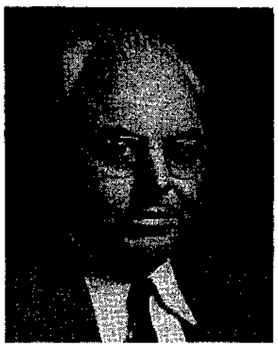

THE AUTHOR: J. W. DEHN has, during the past thirty-two years, been engaged in the development and design of switching circuits for the manual, call indicator, PBX, step-by-step, panel and crossbar systems. His work with the crossbar systems was principally on the common control circuits—markers and senders and their associated test circuits as used in the No. 1 crossbar, tandem crossbar, No. 4 toll crossbar, and the No. 5 crossbar systems. At present, he is supervisor of the group responsible for the development and design of the common control circuits for the No. 5 crossbar system. During World War II he developed communication systems for the Signal Corps, and trained military personnel in the operation and maintenance of the equipment. Mr. Dehn is a graduate of the Polytechnic Institute of Brooklyn with the degree of Electrical Engineer.