

# electronics

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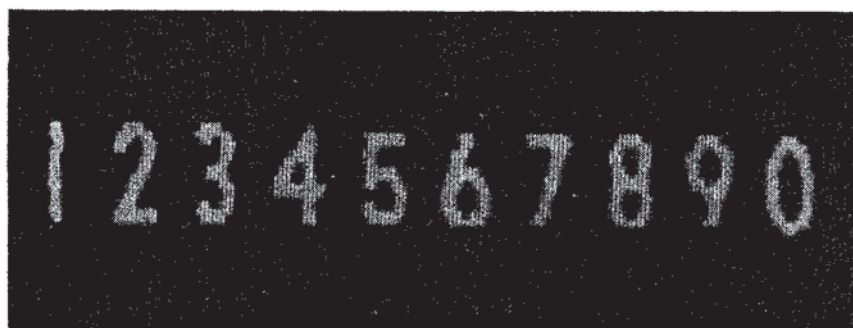
By A. J. Strassman

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# Character Recognition

**SUMMARY** — Photoelectric scanner analyzes printed numerals and provides electrical output usable in computers and other business machines. Reader recognizes 400 characters per second. Operation is independent of type style or size of number above minimum width



Numerals printed by character reader

By M. H. GLAUBERMAN

Senior Engineer  
Laboratory for Electronics, Inc.  
Boston, Massachusetts

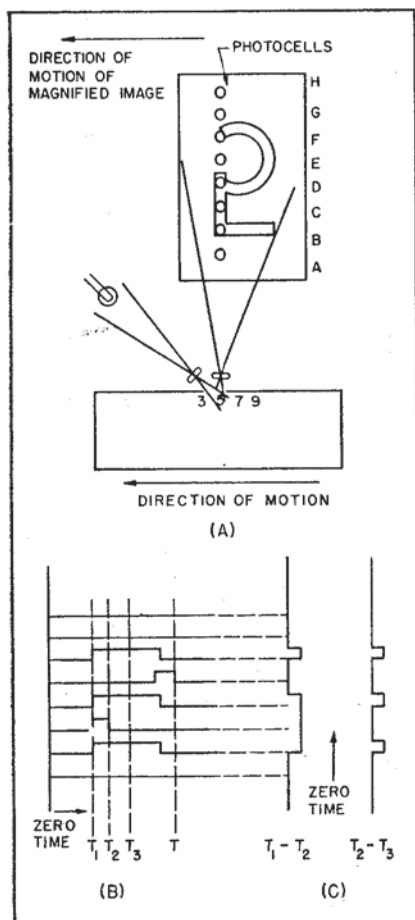


FIG. 1—Optical system of photoelectric scanner

**T**HIS READER recognizes Arabic numerals as printed matter passes through it.

Paper is not restricted as to color, thickness, opacity, roughness or quality. Ink need have no special qualities. The depth of the impression on the paper is of no significance, and at no time does the reader come into contact with the paper.

The character reader cannot read all type styles, but is not dependent on any one style. Minimum type width is approximately  $\frac{1}{16}$  in. for the widest digit. There is no restriction on maximum type width. The reader is not dependent on the height of the type providing the size is not larger than the aperture of the reading station. A common type height is about  $\frac{1}{8}$  inch. Most print imperfections will not impair recognition.

With checks moving into the reader at 16 per second, it recognizes 400 characters per second. The reader is able to read 1,600 characters per second, however, and could be made to operate at twice this speed.

The reader is designed to operate

serially and sorts by successive passes.

## Photoelectric Scanner

The scanner consists of a column of photocells whose outputs are modulated by the black portions of characters. The photocells are sequentially gated into a common buffer. Figure 1A shows how a magnified image of a number is projected on the photocells. Figure 2 shows the scanner circuits.

Figure 1B shows the photocell outputs. The effect of sequentially gating the outputs into a common buffer is shown in Fig. 1C.

Table I—Pulse-Code Combination

Total Pulses Per Scan	Long-Black Pulses Per Scan	Coded Combination
1	0	10
1	1	11
2	0	20
2	1	21 21'
2	2	22
3	0	30 30'
3	1	31

Note that the first digit of the coded combination represents the total number of black pulses per scan and the second digit represents the number of long black pulses per scan

# for Business Machines

There are photocells above and below those required to cover the number to accommodate changes in the vertical registry. See Fig. 3. Each photocell is an input to a gate whose other input is connected to a tap of a multiple-tapped delay line. The outputs of the gates are combined in the common buffer *B*.

Each photocell is individually connected to network *B* by sending a pulse down the multiple-tapped delay line. A pulse sent down the delay line corresponds to a scan. No attempt is made to synchronize the start of a scan with the entry of a character under the column of photocells.

The uncertainty of the start of the scan with respect to the edge of the character to be scanned is called horizontal registry. The character reader overcomes this registry problem by utilizing the first scan not to recognize the character but to tell the recognition circuit to look for recognition on the second scan.

## Pulse Generator

The waveforms at the output of combining network *B* appear as in Fig. 1C. The total pulse generator produces one pulse for each black region of the number and serves as a noise filter in that an input pulse must exceed a certain width for an output pulse to be generated.

The long-black pulse generator (see Fig. 4) is also a pulse-width detector. In this case a pulse must exceed a predetermined length for a long-black pulse to be generated. For example, a pulse must equal or exceed the length shown in Fig. 1C.

The output of the total pulse generator and of the long-black pulse generator, along with the system trigger, are next sent to the encoder unit. Three pulses, each appearing once during every scan period, are derived from the tapped delay line and also sent to the encoder. These pulses, in the order of their time sequence, are the comparison pulse, the read-out pulse and the reset pulse.

Six instructions constitute the

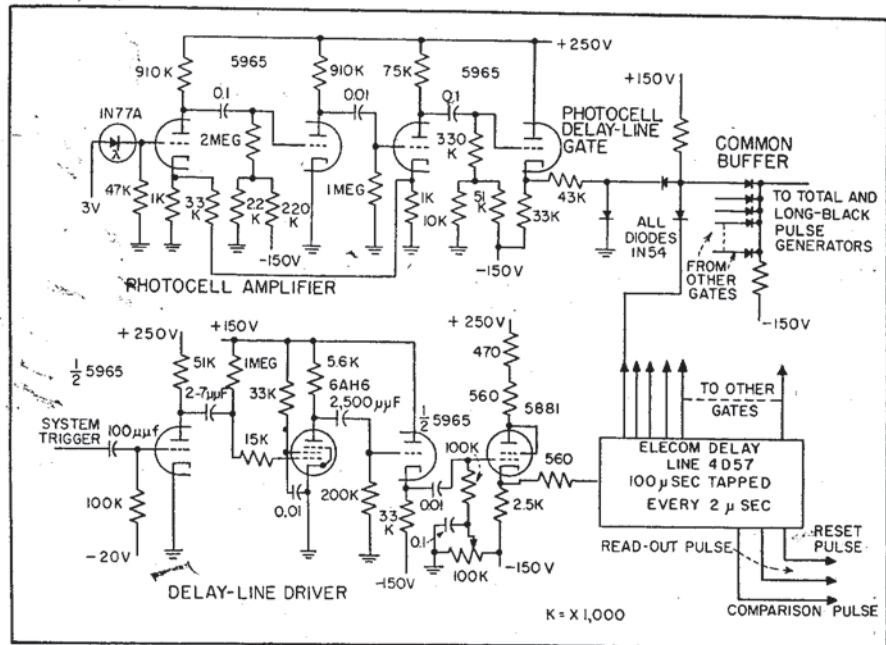


FIG. 2—Input section showing photodiode and delay line

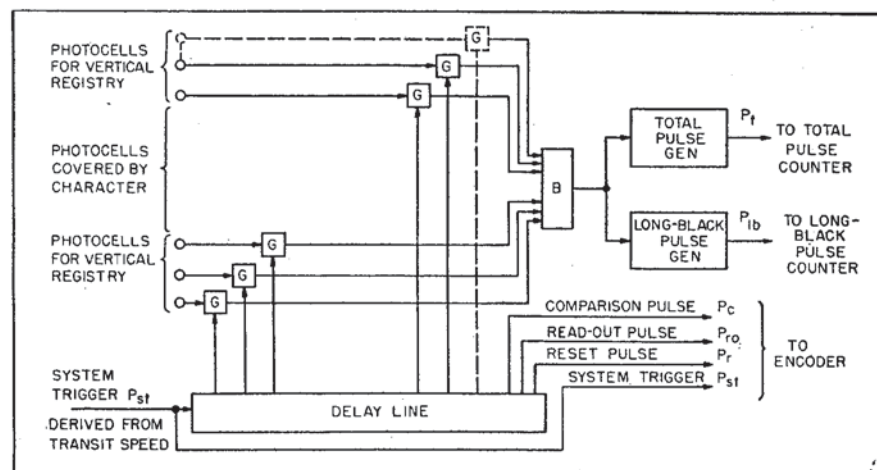


FIG. 3—Scanning station of character reader

program of the character reader.

(1) Count the total number of black pulses per scan.

(2) Count the number of long-black pulses per scan.

(3) Combine the results into discrete combinations as shown in Table I.

(4) If adjacent scans are not identical, put the most recent scan into shift-register storage and shift the register.

(5) If adjacent scans are identical, put nothing into storage and do not shift the register.

(6) When there is no character under the reading station, advance

the register but put nothing into storage.

A block diagram of the encoding unit shown in Fig. 5. The system trigger  $P_s$ , operates an electronic switch which routes the total pulses  $P_t$  alternately into total-pulse counter *A* and total pulse counter *B* through gates  $G_a$ . The electronic switch also routes the long-black pulses  $P_{ib}$  into long-black counter *A* and long-black counter *B*, alternately, through gates  $G_b$ .

## Scan Comparison

Alternately switching input information  $P_t$  and  $P_{ib}$  into pairs of



Table II—Shift Register Storage (Numeral Three)

1 Scan	2 Total	3 Long	4 Code	5 Identity	6 Read-in	7 Shift	8 Interrogate	9 1st read-in in core row	10 2nd read-in in core row	11 3rd read-in in core row	12 4th read-in in core row
1	1	0	10	no	yes	yes	no	1	—	—	—
2	2	0	20	no	yes	yes	no	2	1	—	—
3	2	0	20	yes	no	no	no	2	1	—	—
4	2	0	20	yes	no	no	no	2	1	—	—
5	2	0	20	yes	no	no	no	2	1	—	—
6	3	0	30	no	yes	yes	no	3	2	1	—
7	3	0	30	yes	no	no	no	3	2	1	—
8	1	1	11	no	yes	yes	no	4	3	2	1
9	0	0	—	no	—	yes	no	5	4	3	2
10	0	0	—	no	—	yes	no	6	5	4	3
11	0	0	—	no	—	yes	next shift pulse yes	7	6	5	4
12	0	0	—	no	—	yes		x	7	6	5

identical counters provides for comparing adjacent scans for identity. The counters hold the input information until they are reset by reset pulse  $P_r$ , which is electronically switched through gates  $G_s$  once each scan alternately to reset both  $B$  counters and both  $A$  counters.

The comparison is accomplished in gates  $G_s$  once each scan after the counters have received their input information and at a time determined by the comparison pulse  $P_c$ . One of the six comparison gates will respond only when the input data  $P_i$  and  $P_{i+1}$  have remained constant from one scan to the next.

Scan-to-scan identity in the long-black counter allows the comparison pulse to appear at the output of buffer  $B_{41}$ . Scan-to-scan identity in the total-pulse counter allows the comparison pulse to appear in the

output of buffer stage  $B_{41}$ . A pulse appears at the output of both of the buffer stages only when scan-to-scan identity is indicated by both the total-pulse and the long-black counters. This is the necessary condition to pass the signal through gate  $G_s$  to the identity-gate generator.

After the  $A$  and  $B$  counters have been compared for identity they are read out by read-out pulse  $P_{ro}$ . If there has been no identity the read-out pulse appears at the output of gate  $G_A$ . The electronic switch then allows the read-out pulse to appear alternately at the input of the  $G_s$  gates. It enables the outputs of either the  $A$  or the  $B$  counters to appear at the outputs of the appropriate  $G_s$  gates.

The  $B_s$  buffers then show the accumulated count per scan inde-

pendently of whether the counts appear in the  $A$  counters or the  $B$  counters. The first scan of the character is detected in buffer  $B_s$  and used to generate an inhibiting signal whose duration is  $1\frac{1}{2}$  scan periods. This inhibiting signal, applied to gate  $G_s$ , prevents the recognition of an identity on the first two scans of the character. Subsequent scans of the character are prevented from generating additional inhibiting gates by the  $1\frac{1}{2}$ -character-period gate generator applied to gate  $G_i$  to disable it for the duration of the number.

### Coding

The coded combination (Table I) of total-pulse and long-black counters is formed by the  $G_m$  gates. Only one or none of these five combinations can appear during one scan. The prime combinations are obtained in the  $B_m$  buffers.

The instruction to put into storage is accomplished implicitly whenever a signal appears on one of the five code-combination lines. The storage register is shifted or advanced by the system trigger  $P_s$ , when the trigger is enabled to appear at the output of gate  $G_n$ . System trigger  $P_s$  appears and the register is enabled to advance when a permissive signal appears on either one of the two inputs to the  $B_n$  buffer. One input is connected to the identity-gate generator and allows the register to shift unless there is an identity.

Between characters, the outputs of both the total-pulse counter and the long-black counter are zero. This combination of 00 is not sensed for identity in the  $G_s$  gates; therefore no identity signal can be generated. Also, since the code combination 00 has not been explicitly

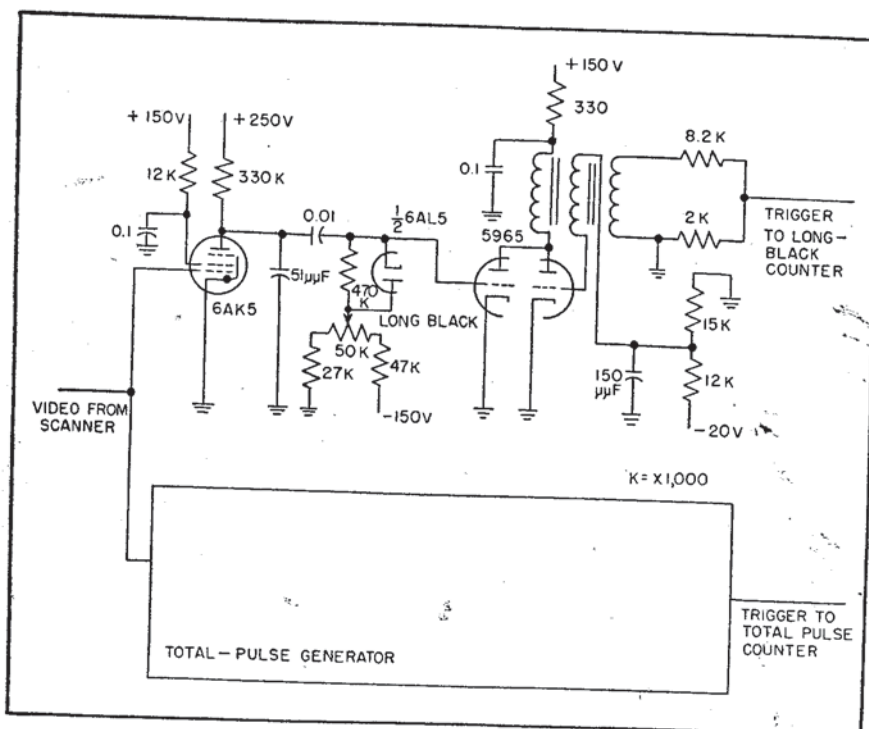


FIG. 4—Long-black pulse generator is pulse-width detector

formed in the  $G_m$  gates, there is nothing to put into storage.

Readiness for interrogation is detected in buffer  $B_0$  which is connected to the seventh and last stage of storage. The first signal at the output of  $B_0$  passes through gate  $G_0$  and generates a gate whose duration is  $1\frac{1}{2}$  scan periods. This gate connected to  $B_n$  enables the register to advance on the next system trigger.

Subsequent signals at the output of  $B_0$  during the character storage time are prevented from passing through gate  $G_0$  by the  $1\frac{1}{2}$ -character-period gate generator, the latter

being energized by the system trigger that occurs after the first output signal at  $B_0$ . This particular system trigger is broadened in the matrix interrogation-pulse generator and is then used in the diode matrix.

### Shift Register Storage

Each block in Fig. 6A represents one magnetic core. There are thirty-five cores arranged in five columns of seven each. Each of the five columns is used to store one of the five discrete code combinations.

Information is always read into row 1 and remains in row 1 until

a shift signal is applied whereupon the content of row 1 is advanced to row 2.

Access to the information in the cores is available only during the shift-pulse time. As indicated in Fig. 6A, a single shift signal suffices to advance all thirty-five cores.

Figure 6B shows the scanned character THREE. The total number of pulses  $T$  in scan one is one. There are no long pulses  $L$  (code 10). For scan two:  $T = 2$ ,  $L = 0$  for code 20. Scans three, four and five also yield code 20. In scans six and seven,  $T = 3$ ,  $L = 0$  for code 30. Scan eight contains only one long pulse

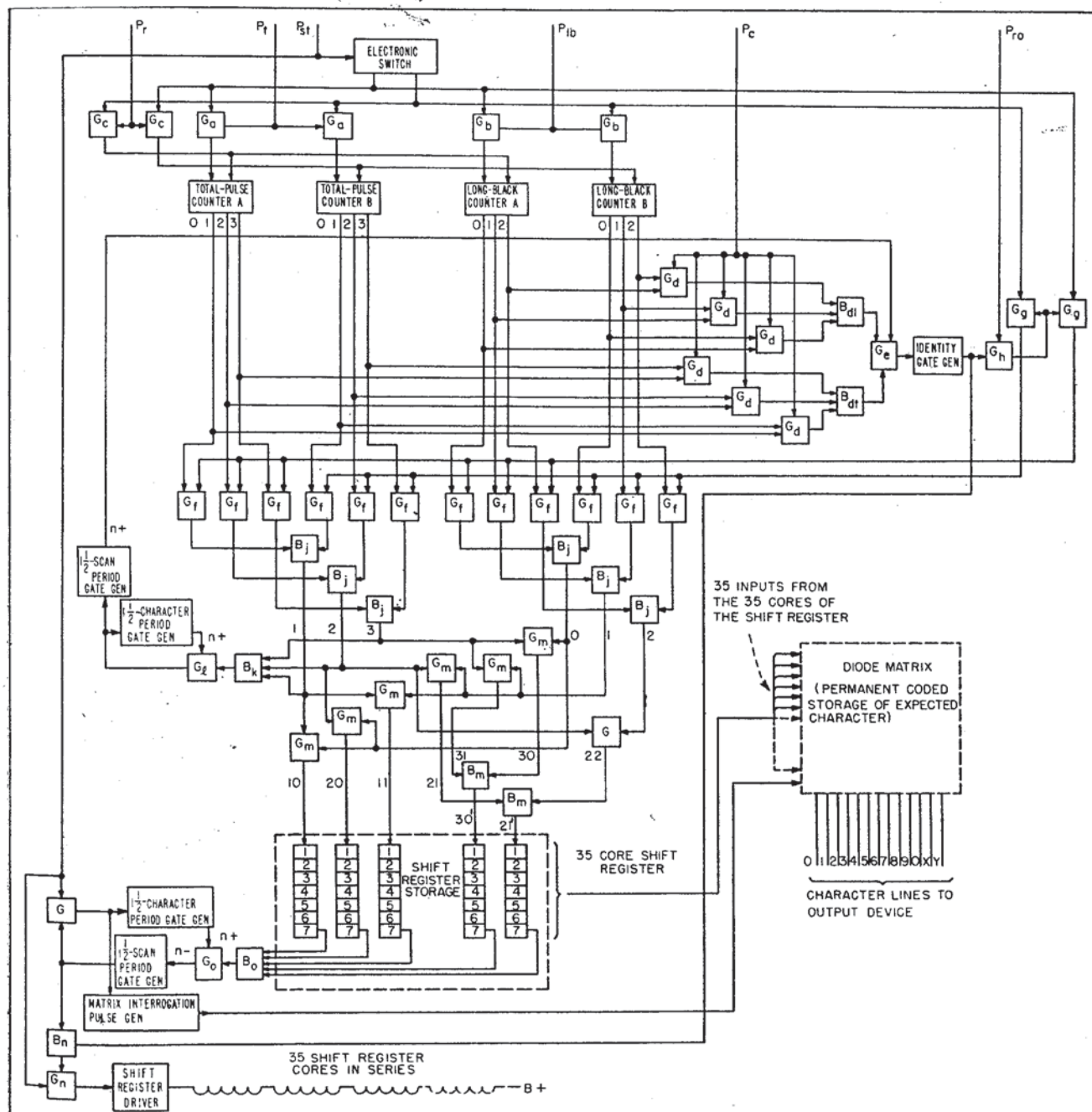


FIG. 5—Encoding unit which carries out the instructions comprising the program of the character reader



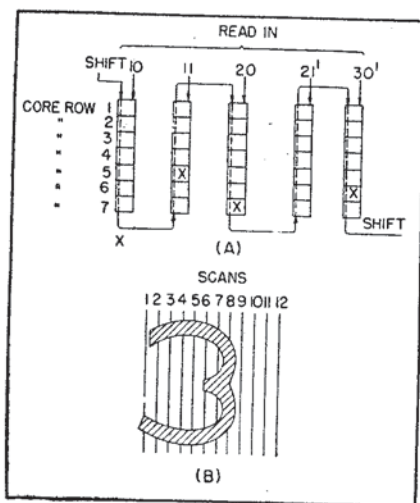


FIG. 6—Shift register storage with blocks representing magnetic cores (A) and the character THREE to be scanned (B)

which is indicated by code 11.

During scans nine through twelve there is nothing under the reading station;  $T = 0$ ,  $L = 0$  and no code exists for this combination. The contents of this paragraph are tabulated in columns 1 through 4 of the chart in Table II. The remainder of the columns show how the coded data gets into storage and is advanced to a known position.

Column 5 shows whether or not the code combinations of adjacent scans are identical. Although scans 9 through 12 are similar to the naked eye, the encoder does not indicate identity because it does not explicitly sense for the 00 combination. This is the significance of the 4 dash marks at the bottom of column 4.

Column 6 indicates that information is read into the shift register only on scans 1, 2, 6 and 8. Referring to column 4, information is read into the core columns that store 10, 20, 30' and 11 in that time sequence. Column 7 shows that the register is advanced whenever there is no scan-to-scan identity (column 5).

Column 9 shows how the first bit of information (code 10) read into the register progresses from the first to the seventh row of cores and then out of the cores. Columns 10, 11 and 12 show that the subsequent read-ins (codes 20, 30 and 11) will occupy core rows 6, 5 and 4 respectively at the time the first read-in is at core-row 7.

When the first read-in has been shifted out of the cores, codes 20,

30 and 11 occupy rows 7, 6 and 5. The blocks in Fig. 6A indicate the positions in storage of the four code combinations that result from scanning the figure THREE. This is in accordance with the basic instructions built into the character reader at the time the interrogation pulse appears to check which character has passed under the reading station. The signal derived from the first scan shifting out of the register signifies to the reader that the scanned character has now been read into a known position in storage. The register must be interrogated for recognition on the next system trigger.

### Diode Matrix

The diode matrix indicated on the encoder block diagram of Fig. 5 is shown in detail in Fig. 7. It consists of five groups of vertical lines, seven lines per group, which can be interlaced as many times as there are characters to be recognized. Each of the seven vertical lines per group is connected to one horizontal row of the shift-register cores.

The expected character configuration in a known position in the register is stored by connecting horizontal and vertical lines through gates and buffers. Take, for example, the number THREE whose code is 10, 20, 30, 11. When the 10 is shifted out of the seventh row of cores the machine is instructed to interrogate the matrix at the time

the next shift pulse occurs.

At this new time the 20 will be in core-row 7, the 30 in row 6 and the 11 in row 5. Referring to horizontal line A in Fig. 7, gate  $G_a$  is formed from the first wire of the 20 register, the second wire of the 30 register and the third wire of the 11 register. The references to wires are respectively synonymous to first, second and third coded scans. The final connection to gate  $G_a$  is the interrogation pulse.

The output of gate  $G_a$  is called the THREE wire and its significance is that whenever the reader recognizes the number THREE a pulse appears on this and only this line. The pulse then operates terminal equipment such as a sorter, printer or accumulator.

Horizontal group B represents a more general case where a number can be represented by two sequences of coded scans. Recognition of the character yields a pulse at the output of either one of the two gates and the buffer combines the two possible output lines to a single line.

The remaining horizontal wires are shown to indicate that the reader will recognize the remaining nine decimal digits.

The author thanks M. Hale, S. Butcher, R. Preece and other members of the Laboratory for Electronics for their contributions to this work. This development was sponsored by the Chase Manhattan Bank.

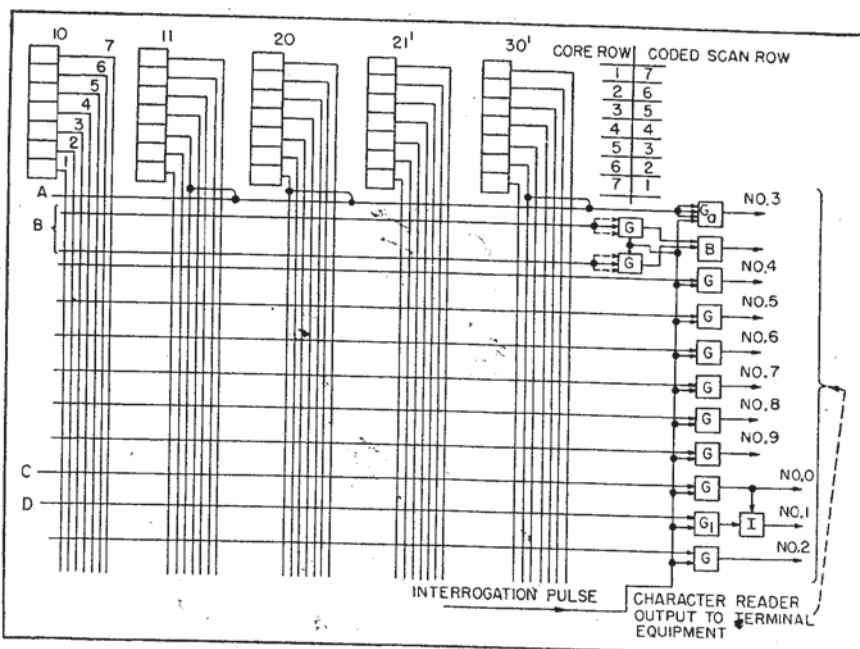


FIG. 7—Diode matrix gives permanent coded storage of expected character