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[54] **DIGITAL CODE TRANSLATOR APPARATUS**

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[52] **U.S. Cl.** ..... **340/347 DD,** 178/26 R

[51] **Int. Cl.** **H03k 13/00,** H04l 3/00

[58] **Field of Search** ..... 178/26, 26 A, 36; 340/147 T, 347 DD

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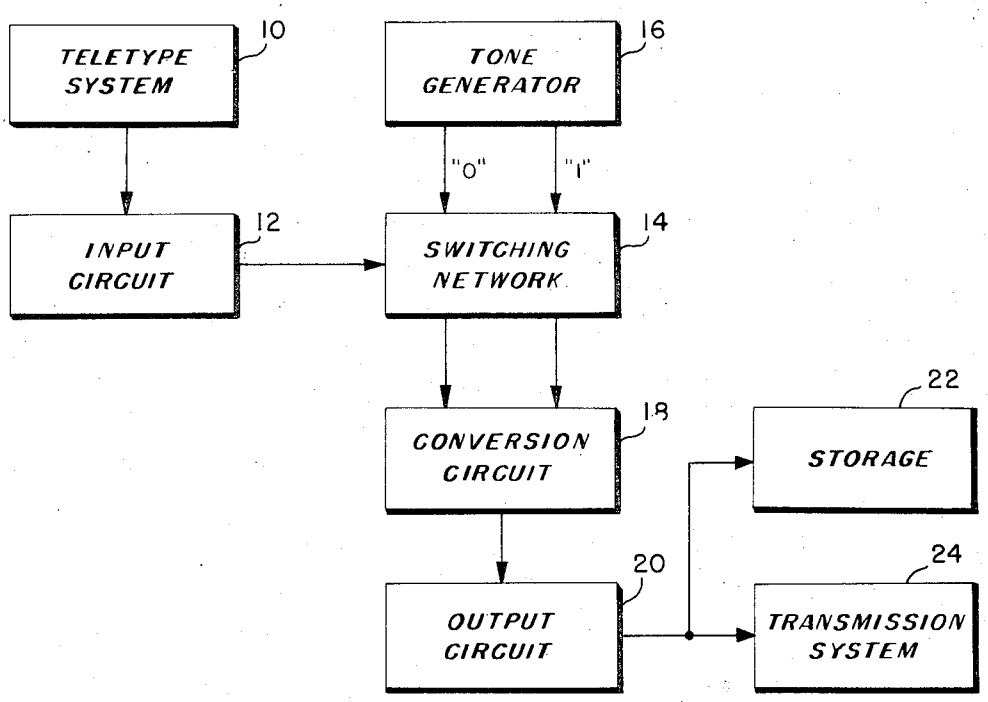
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[57] **ABSTRACT**

Apparatus for increasing substantially the amount of information that can be transferred by teletype communication systems in a given amount of time without additional increase in bandwidth, transmission facilities, or teletype system equipment. At a transmitting station, parallel, fixed-place digital-coded message characters are translated to serial, variable-place, digital-coded message characters. After reception at a remote station, the received characters are retranslated into output characters which are equivalent to the parallel, fixed-place characters transmitted. The conversion apparatus essentially comprises a switching network which produces in a novel manner digital representations of characters which are equivalent to the corresponding character to be translated.

7 Claims, 6 Drawing Figures



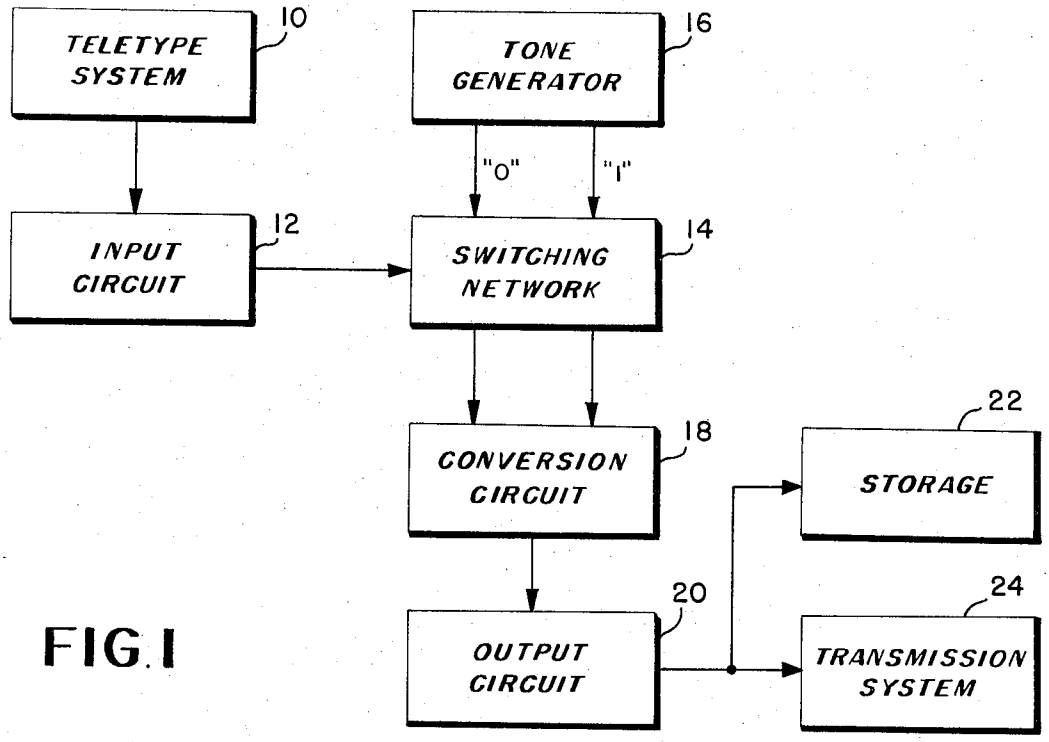

TELETYPE SYSTEM
10
TONE GENERATOR
16
"0"
"1"
INPUT CIRCUIT
12
SWITCHING NETWORK
14
CONVERSION CIRCUIT
18
STORAGE
22
OUTPUT CIRCUIT
20
TRANSMISSION SYSTEM
24

FIG. 1

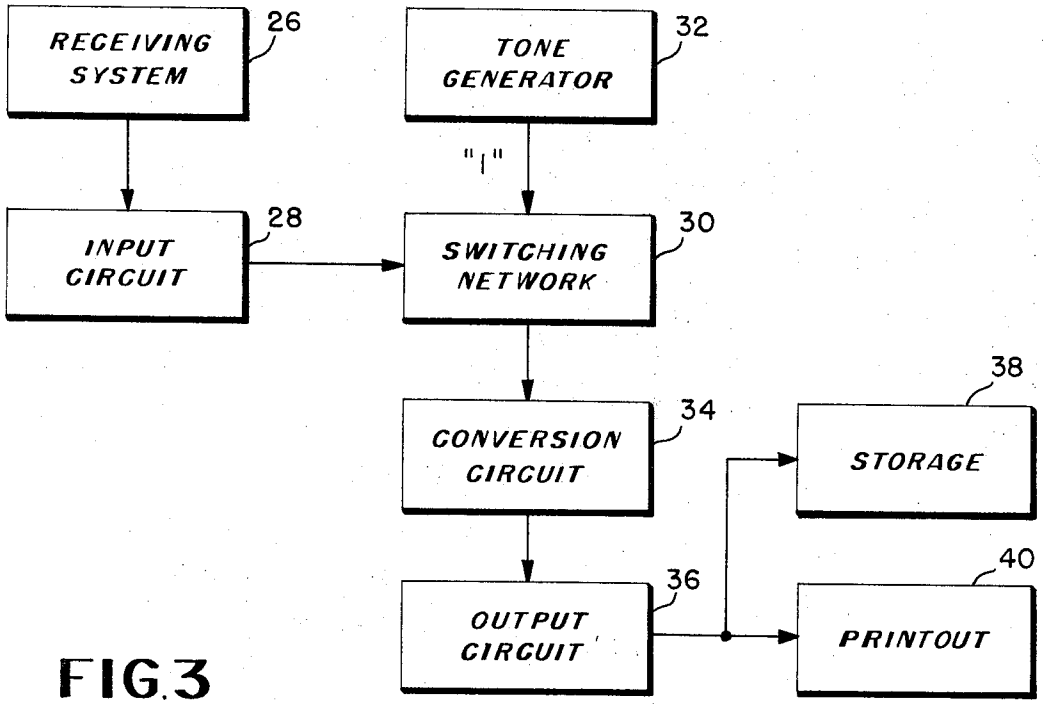

RECEIVING SYSTEM
26
TONE GENERATOR
32
"1"
INPUT CIRCUIT
28
SWITCHING NETWORK
30
CONVERSION CIRCUIT
34
STORAGE
38
OUTPUT CIRCUIT
36
PRINTOUT
40

FIG. 3

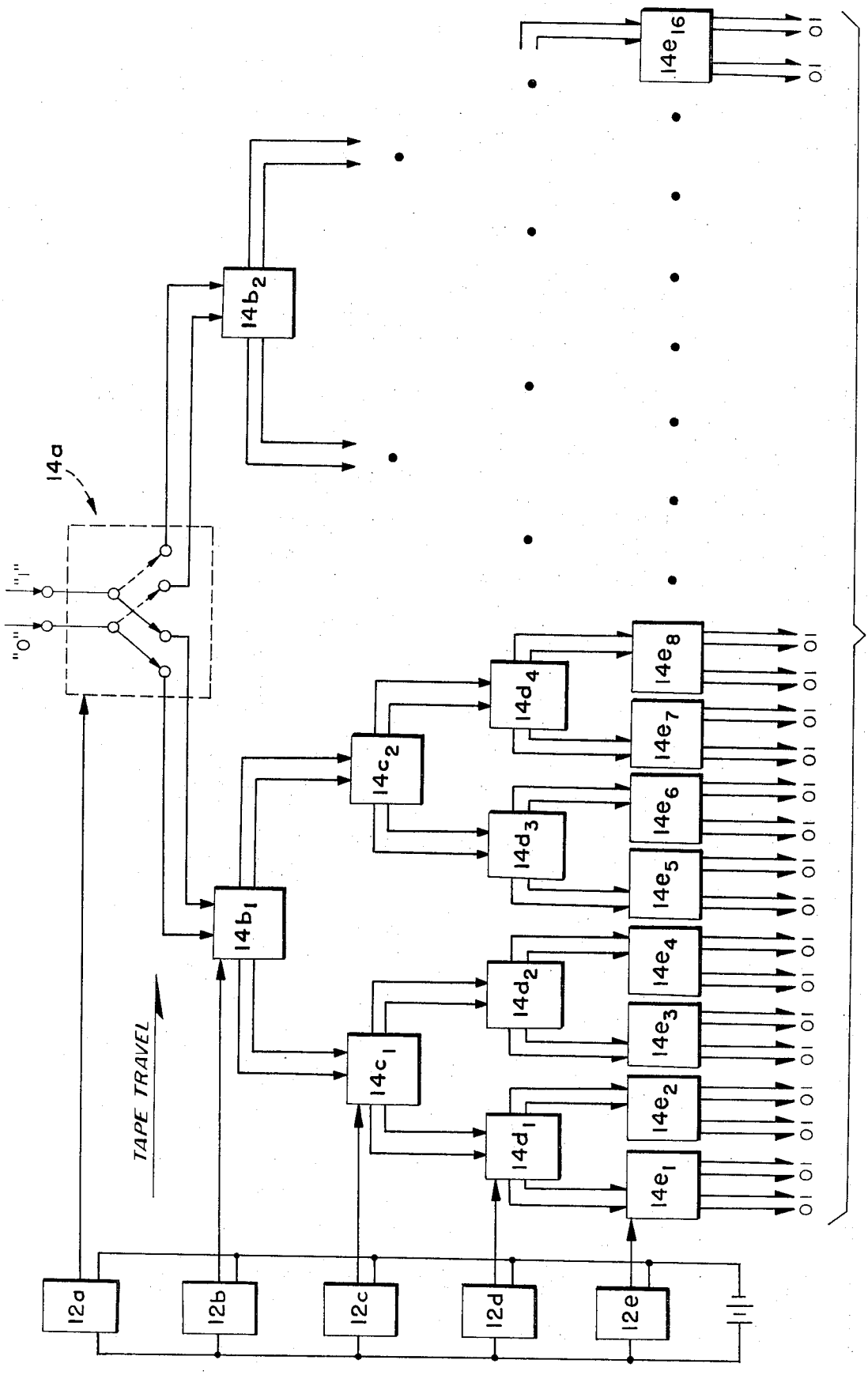

14a
"1"
"0"
14b2
14b1
14c2
14c1
14d4
14d3
14d2
14d1
14e16
14e8
14e7
14e6
14e5
14e4
14e3
14e2
14e1
01
12a
12b
12c
12d
12e
TAPE TRAVEL
TO CONVERSION CIRCUIT 18

FIG. 2a

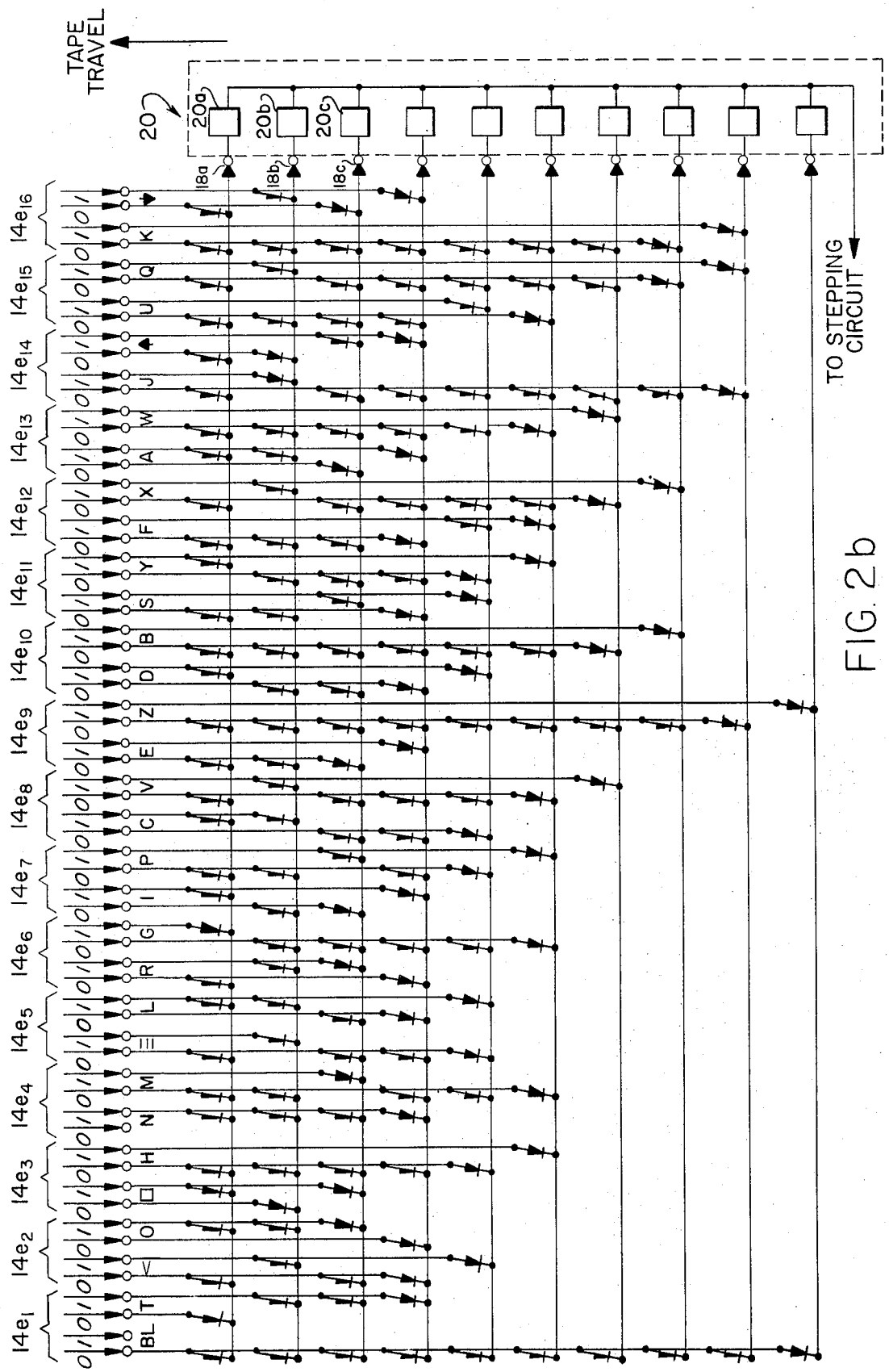
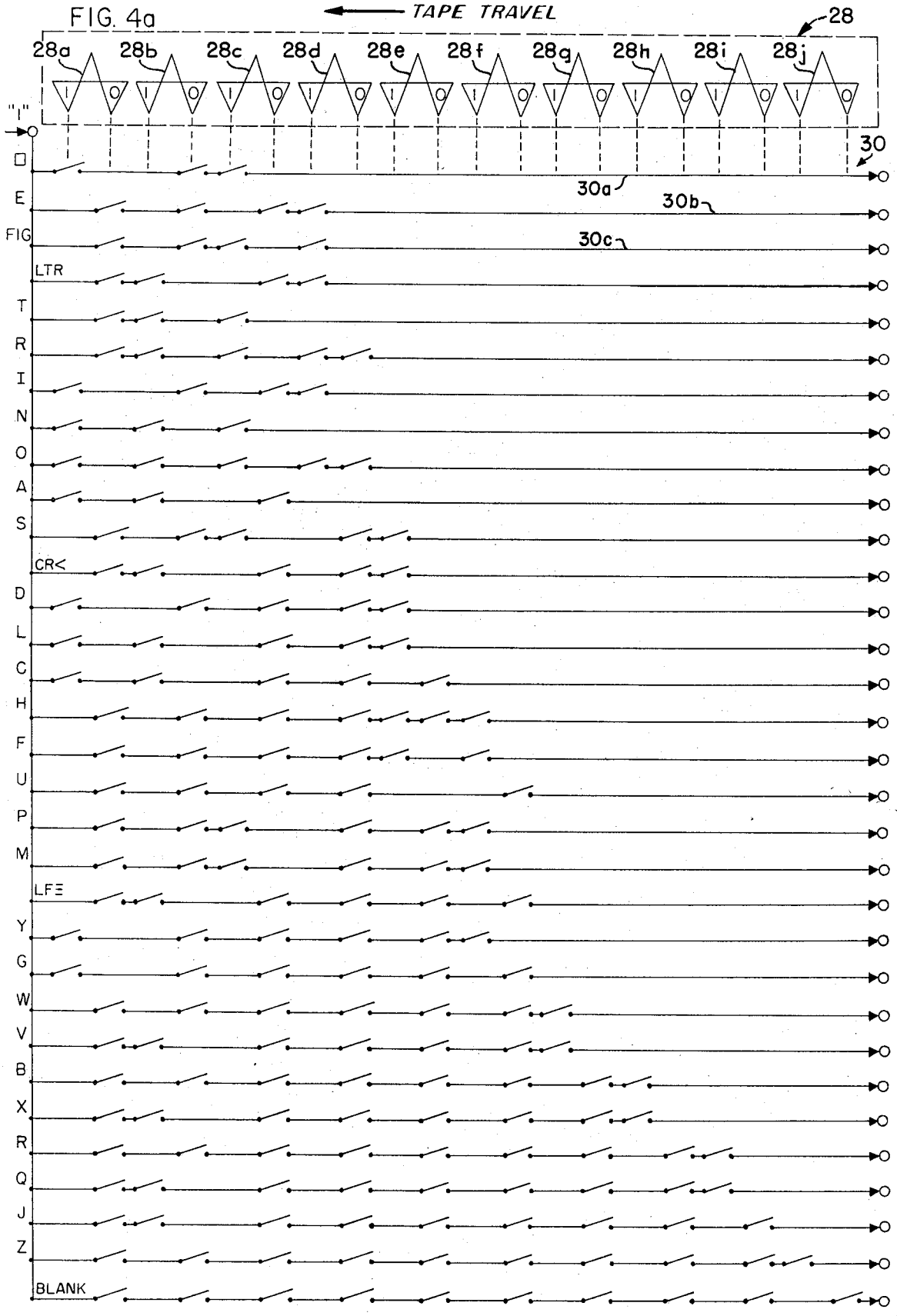

TAPE TRAVEL
20
20a
20b
20c
18a
18b
18c
TO STEPPING CIRCUIT
14e1
14e2
14e3
14e4
14e5
14e6
14e7
14e8
14e9
14e10
14e11
14e12
14e13
14e14
14e15
14e16
BL
T
V
O
H
N
M
L
R
G
I
P
C
V
E
Z
D
B
S
Y
F
X
A
W
J
U
Q
K

FIG. 2b

FIG. 4a


TAPE TRAVEL
28
28a
28b
28c
28d
28e
28f
28g
28h
28i
28j
"1"
30
30a
30b
30c
LTR
CR<
LFE
BLANK

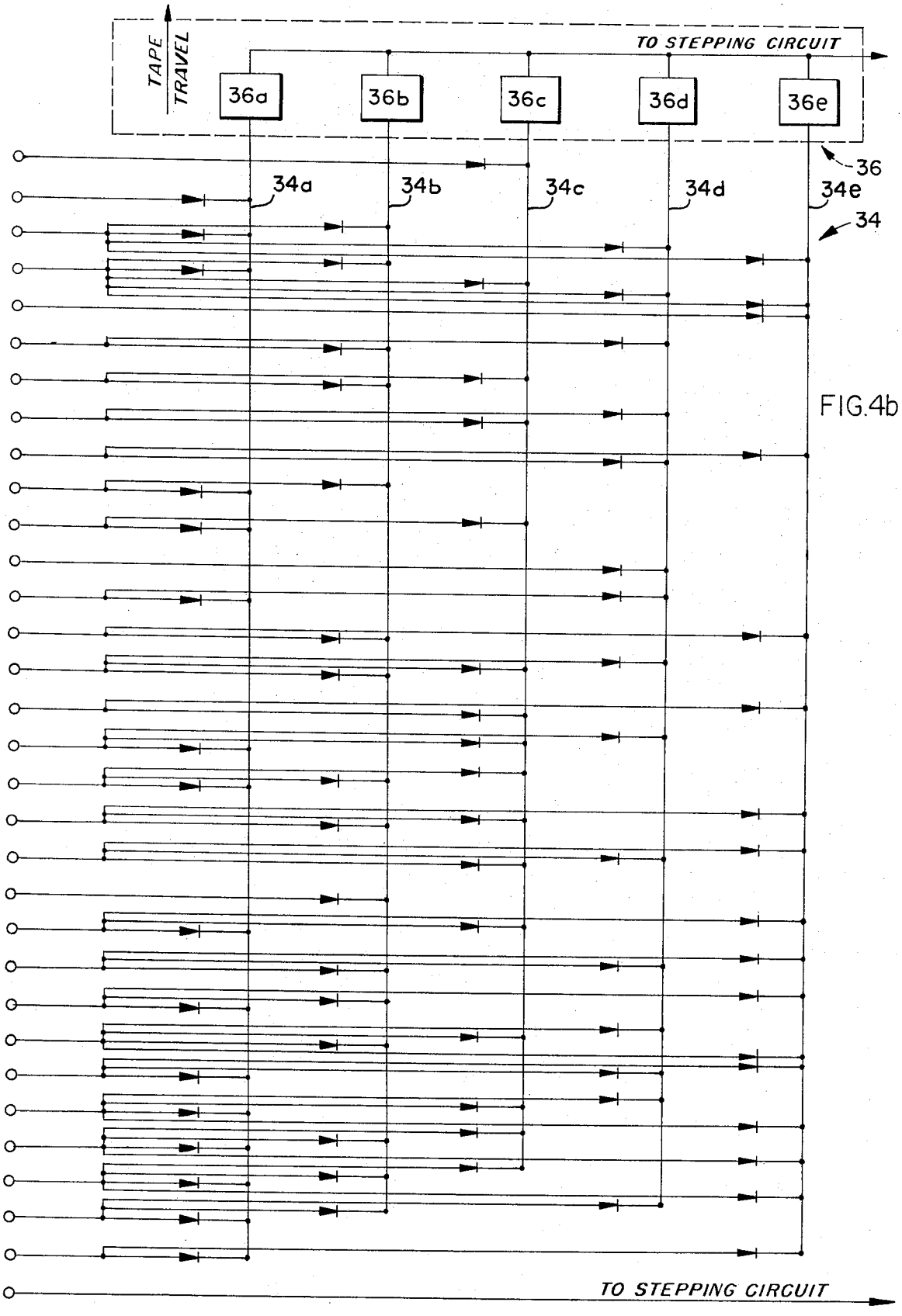

TAPE TRAVEL
TO STEPPING CIRCUIT
36a
36b
36c
36d
36e
36
34a
34b
34c
34d
34e
34
TO STEPPING CIRCUIT

FIG.4b

DIGITAL CODE TRANSLATOR APPARATUS

BACKGROUND

Existing Teletype transmission systems generally employ a digital code that is fixed in the number of digits required for operation. Because the length of the code is fixed, the apparatus cannot take advantage of statistical characteristics of the information being transferred. Furthermore, machine instructions must also be transmitted within the digits thereby drastically reducing system efficiency to about two-thirds of its potential value. Since electromechanical design and construction features of the prior art preclude the feasibility of upgrading these machines, code improvement is thus the only possible upgrading method available. The present invention comprises a code improvement which enables a transfer of a substantially greater amount of information in a much shorter length of time without additional increase in Teletype equipment.

SUMMARY OF THE INVENTION

In Teletype communication systems, apparatus are disclosed for converting Baudot-coded messages into Huffman-coded messages for transmission and reconverting same into Baudot for recording upon reception. Baudot messages are read by parallel-input apparatus to produce a digital signal which is unique for each different character read. A pair of complementary, digital signals are coupled through a switching network to one of 32 output terminal pairs in response to the digital signal. The output is coupled simultaneously to selectively predetermined ones of 10 parallel signal paths, and the resulting outputs are then sequentially recorded and transmitted. Upon reception, the received messages are read by series-input apparatus to produce a unique digital signal for each different character read. A digital signal is coupled through a switching network to one of 32 output terminals in response to the analog signal. The signal is then coupled simultaneously to selectively predetermined ones of five parallel signal paths, and the resultant outputs are then recorded simultaneously wherein the parallel, five-place digital word recorded represents a Baudot-coded output character equivalent to a corresponding input character read before transmission thereof.

OBJECTS OF THE INVENTION

It is the primary object of the present invention to provide apparatus for Teletype transmission that will allow the transfer of a substantially greater amount of information in a much shorter length of time without any additional increase in circuit bandwidth, transmission facilities, or Teletype system equipment.

It is another object to provide apparatus for converting fixed-length digital-codes into variable-length digital-codes and vice versa.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** represents a simplified block diagram of apparatus embodying the present inventive concept for achieving a code translation from a fixed-length digital code to a variable-length digital code.

FIGS. **2**(a) and **2**(b) represent simplified electrical schematic diagram of the circuit of FIG. **1**.

FIG. **3** illustrates a simplified block diagram of code translation apparatus embodying the present inventive concept for translating from a variable-length code to a fixed-length code.

FIGS. **4**(a) and **4**(b) are electrical schematic diagrams of the apparatus of FIG. **3**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The inventive concept of the present invention is illustrated generally in the block diagrams of FIG. **1** and FIG. **3**. The Teletype apparatus shown in FIG. **1** can translate a message character from a fixed-length code such as the 32 character Baudot code to a variable-length digital code such as the Huffman code. A message originator Teletype system **10** provides a Baudot-coded message on paper tape to an input circuit **12**. The paper tape has punched thereon five-place, digital characters which comprise the message to be transmitted.

The input circuit **12** is triggered by the tape input and produces a digital output which is fed to a switching network **14**. The switching network also receives a complementary digital pair, i.e., "1" and "0," from the tone generator **16**. The digital pair is coupled through the switching network **14** by the output of the input circuit **12**.

The output of the network is coupled to a conversion circuit **18** to convert the fixed-place code to a variable-length code in a manner to be described hereinafter. The conversion network essentially comprises a prewired matrix having diode isolation as shown in detail in FIG. **2**(b).

The converted output is fed into an output circuit **20** which can comprise a paper tape punch or a magnetic tape machine. The resulting output can be coupled to a storage device **22** or to a transmission system **24**.

As shown in FIG. **2**(a), the input circuit **12** comprises five, parallel sensors, each of which is responsive to a different one of the five, parallel digits represented by the five-place paper tape from the Teletype system **10**. The tape travels through the circuit **12** in the direction shown by the arrow. Each sensor, **12***a*, **12***b*, **12***c*, **12***d*, and **12***e* is operatively connected to the switching network **14**, which is also shown in detail in FIG. **2**(a).

The sensors are responsive to the parallel input representing a particular character to produce a digital output only when, for example, a hole, ("1") in the paper tape is sensed by the appropriate sensor. An unpunched place ("0") in the paper tape serves as an insulator whereby the corresponding sensor is not energized and hence it produces no output.

The sensors preferably, but not necessarily, comprise electromagnetic devices such as coils on relays, control coils on magnetic amplifiers, or emitter-ground connections on transistors.

The switching network **14** comprises 31, substantially identical, double-pole, double-throw (DPDT) switches which are electrically connected to each other in a symmetrical dichotomy configuration in which the output of the single switch **14***a* is connected to the pair of switches $14b_1$ and $14b_2$. The outputs of $14b_1$ and $14b_2$ are in turn connected to the four switches $14c_1$, $14c_2$, etc., and the outputs of $14c_1$, $14c_2$, etc., are connected

to the eight switches $14d_1$, $14d_2$, etc., and on to the 16, output switches $14e_1$, $14e_2$, etc.

The switches designated *a*, *b*, *c*, *d*, or *e*, are responsive to the output digital signal from the corresponding sensors **12***a*, **12***b*, **12***c*, **12***d*, and **12***e*, respectively, to switch from the rest position shown by the solid arrows in the detailed drawing of switch **14**a to the energized position shown by the dashed arrows therein. The other 31 DPDT switches are shown. in simplified form to simplify FIG. **2**(a); however it should be understood that the representation thereof would be identical to that of **14***a*.

The operation of the input device **12** and the network **14** will now be illustrated by means of, for example, the character for space (□) which has the Baudot code 00100. As paper tape having SPACE thereon is sensed by the input device **12**, only the sensor **12**c is energized, since only it senses a "1" (hole) in the corresponding digit space. Thus only the four switches, $14c_1$, $14c_2$, etc., are switched from the rest position to the energized position.

Consequently since the sensor **12***a* is not energized, the digital pair (**0**, **1**) from the tone generator **14** is applied to the "rest" terminals of the switch **14***a*.

Likewise, since the sensor **12***b* is not energized, the two switches $14b_1$ and $14b_2$ remain in the rest position, and the "1" and "0" are coupled thereto from the switch **14***a*.

The sensor **12***c* is energized; thus the three switches $14c_1$, $14c_2$, etc., are switched to the energized position indicated by the dashed arrows. Since neither sensors **12***d* nor **12***e* are energized, the corresponding switches remain at rest, and the "1" and "0" are thus outputted at the energized output terminals of the switch $14e_3$ of FIG. **2**(a). It can be seen from FIG. **2**(b) that the output terminals of the switch $14e_3$ correspond by design to the symbol □ for the SPACE input character.

The output of the switch assembly **14** is coupled to the conversion circuit **18** wherein the following action occurs. As shown in FIG. **2**(b), the circuit comprises a prewired matrix with diode isolation and consists of ten parallel lines or signal paths, **18***a*, **18***b*, etc. The output terminal pairs of each of the DPDT switches $14e_1$, $14e_2$, etc., are connected directly to selectively predetermined ones of the paths whereby, for example, the switch $14e_3$ corresponding to the symbol □ for SPACE couples its "1" and "**0**" output simultaneously to the top three paths **18***a*, **18***b*, and **18***c*, in a selectively predetermined order.

A blocking diode is connected between each switch output and any connection therefrom to any one of the ten lines to provide isolation therebetween. Other conventional diode isolation circuits can be used advantageously, and the diode circuit shown herein is merely typical of conventional isolation circuits.

Consequently the output of the top three lines, as read sequentially, is equal to **101.** In can be appreciated that the **101** represents a variable-length, Huffman code SPACE character equivalent to the input fixed-length, Baudot code SPACE character. It can also be seen that each of the 32 input pairs from the sixteen switches $14e_1$, $14e_2$, etc., corresponds to a different one of 32 characters equivalent to the 32 characters normally associated with the Baudot-code, and that the apparatus of FIGS. **1** and **2**(a) and **2**(b) function to translate the characters from one code to another as described.

The sequentially read Huffman-code characters are recorded by the output device **20** which can comprise a magnetic tape device having 10 recording heads **20***a*, **20***b*, etc., as shown in FIG. **2**(b), and in which the tape travels as shown by the arrow. The recorded output can be stored in storage means **22** or transmitted by conventional means **24.**

The tone generator produces a "1" and a "0" to absolutely define the number of digits in the Huffman code since if only a single tone was employed, all Huffman code segments would have ten digits, and the identity of the code segments could not exist. Thus, in FIG. **1** and FIGS. **2**(a) and **2**(b) "1"'s and "0"'s represent positive indicators, and a blank cannot be substituted for a zero as is done in the Baudot code. The tone generator can comprise an audio generator and amplifier circuit.

When each Huffman-code segment is recorded on magnetic tape at the output circuit **20,** the tape mechanism is stepped forward an amount that places the last recorded digit one position beyond the head designated **20***a*, to position clean tape under the tape heads. After the output is stepped forward to the clean tape position, the input tape is then stepped forward one position, thereby initiating a new cycle.

The generation of a Huffman code involves two primary considerations. The first of the finite list of defined characters to be coded which as discussed herein comprises the 32 functions generally associated with the conventional Teletype keyboard. The second consideration is the frequency of occurrence for each character when operating in a closed system involving the total character population. This value is conventionally known as probability.

The Huffman code characters shown at the input of the conversion circuit **18** have a frequency of occurrence (normalized) as shown by the following table and as derived from statistical information:

TELETYPE CHARACTER	FREQUENCY OF OCCURRENCE (NORMALIZED	HUFFMAN CODE SEGMENTS
SPACE	0.116	101
E	0.088	0001
LETTERS	0.070	0011
FIGURES	0.070	0101
T	0.063	0111
R	0.058	0110
I	0.053	1001
N	0.052	1111
O	0.051	1110
A	0.050	1101
S	0.040	00101
CR	0.032	01001
D	0.028	10001
L	0.025	11001
C	0.023	11000
H	0.023	000001
F	0.021	000011
U	0.021	000010
P	0.019	001001
M	0.017	001000
LF	0.016	01001
Y	0.015	100001
G	0.013	100000
W	0.010	0000001
V	0.009	0100001
B	0.007	00000001
X	0.003	01000001
K	0.002	000000001
Q	0.002	010000001
J	0.001	010000000
Z	0.001	0000000001
BLANK	0.001	0000000000

The transmitted information is received at a remote station by apparatus as shown in FIGS. **3** and **4**(a) and 4(b) and which reconverts the message from a variable-place code to a fixed-place code in the following manner. A receiving system **26** receives the Huffman-coded information and its paper or magnetic tape output is fed to the input circuit **28** which is responsive to a Huffman code character in a manner to be described hereinafter. The tape travels through the circuit **28** in the direction shown by the arrow in FIG. **4**(a).

The input unit **28** is triggered by the tape input and produces an analog digital output which is fed to the switching network **30** which also receives a "1" input from the tone generator **32.** The output of the switching network is coupled to the conversion circuit **34** which in turn feeds its output to the output circuit **36.** The output circuit is connected to either storage apparatus **38** or to printout apparatus **40.**

As shown in FIG. **4**(a), the input circuit **28** comprises ten, serial sensors, **28***a*, **28***b*, etc., each of which is capable of identifying a "1," a "0," or a blank. If a digital "1," for example, is read by any one of the ten sensors, the digital "1" portion of the sensor will be energized and will produce an digital output. The digital output energizes all of the switches in the network **30** which are located in a vertical column below the portion. If a "0" is read, the "0" control device for that sensor will be energized thereby closing the vertical column of switches below that particular device. Obviously, no action results when a blank is identified. The input function is a parallel input when considered with regard to the switching action.

At the initiation of the cycle in which the individual Huffman code segments are read and converted to Baudot, the first "1" or "0" is traversed to the left to the first sensor **28***a*. When this position is reached all 10 sensors will have a "1" or a "0" to identify, and one of the three control devices will be energized. Even if all 10 sensors are energized to produce either a "1" or a "0" from the control devices, only one of the 32 horizontal lines of switches will be completely closed to thereby allow a signal from the tone generator **32** to pass through. This selectivity is based upon the fact that each of the 32 characters comprises a unique combination and number of "1" and "0" digits.

Each of the 32 horizontal lines in the conversion circuit **34** of FIG. 4(b) functions as a storage cell for a different and unique code segment and the simultaneous summation of horizontal lines comprises the switching function which produces a character equivalent to the input character.

Each of the horizontal lines from the switch network **30** (except the bottom one which is all "0" responsive) is connected to one or more of the vertical lines **34***a*, **34***b*, etc., which lead to the recording heads **36***a*, **36***b*, **36***c*, **36***d*, and **36***e*. This vertical network of signal paths performs the conversion function which translates the Huffman segments to Baudot segments. Again, diodes provide the necessary isolation.

In the conversion back to Baudot only a digital "1" tone generator **32** is required because in the constant five-place code, a blank and a "0" are the same.

When each Baudot segment has been recorded on the output device **36,** which can comprise a tape perforator, the tape mechanism is also stepped forward by an output from any of the **32** switches.

Thus, it can be appreciated that a novel concept has been disclosed for improving the efficiency of Teletype communication systems, by providing approximately 65 percent greater information transfer rate or capacity with respect to existing techniques.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

It can be appreciated that the components shown in the figures are merely exemplary and that depending on the requirements and resources of a user, electromechanical relays, vacuum tubes, solid state devices, saturable reactors, electrical optical switches, or pneumatic switching devices can be used to practice the inventive concept herein disclosed.

What is claimed is:

1. Apparatus for converting Teletype message characters represented by fixed-length, parallel, digital codes into equivalent characters represented by variable-length, serial, digital codes and comprising:

parallel input means for reading paper tape containing said message characters and being responsive thereto to produce a parallel output sequence different for each character read thereby and comprising a plurality of digital signals having either substantially equal selectively predetermined amplitudes or zero amplitudes;

means for generating first and second complementary binary digits;

switch means connected to the output of said means and being responsive to said output sequence to pass said first and second binary digits through a selectively predetermined electrical path in said switch means to produce at the output thereof a simultaneous parallel, digital output,

said digital output comprising a variable number of said first and second binary digits having a selectively predetermined parallel sequence wherein said variable number and sequence are unique for each different input character read by said input means;

means for converting said parallel output sequence into a substantially identical serial output sequence and comprising a variable-length, serial digital code; and,

means for recording said serial output sequence.

2. The apparatus of claim **1** wherein said input means comprises a parallel bank of electromagnetic relays.

3. The apparatus of claim **1** wherein said means for generating said binary digits comprises a tone generator.

4. Apparatus for converting Baudot-coded messages wherein five parallel digits define an input character, into Huffman-coded messages wherein a variable number of serial digits define an output character equivalent to said input character and comprising:

input means for reading paper tape containing Baudot-coded messages,

said input means comprising five parallel sensors, each of which is responsive to a different one of said five parallel digits to produce simultaneously with every other one of said sensors, an output signal if a given digit is sensed and no output signal if the complementary digit is sensed;

tone generator means for producing first and second complementary digits;

switch network means having two input terminal pairs and 32 output terminal pairs and being responsive to said output signals from said input means to couple said first and second digits to one of said two input terminal pairs,

said switch network means being operatively connected to said input terminal means and being responsive to the output thereof to couple said first and second digits from said tone generator means to a selectively predetermined one of said two input terminal pairs, and being further responsive thereto to pass said digits through said network to a selectively predetermined one of said 32 output terminal pairs;

output means connected to the output of said switch means,

said output means comprising ten parallel channels, wherein each of said 32 output terminal pairs is connected to a different number of selectively predetermined ones of said channels;

indicator and recorder means for reading and recording the output from each of said ten channels sequentially to thereby produce a serial, digital output.

5. The apparatus of claim **4** wherein said switch means comprises 31, double-pole-double-throw switches connected in a dichotomy network configuration with one switch at the input and sixteen switches at the output thereof.

6. The apparatus of claim **4** wherein said parallel signal paths are connected to said output terminal pairs by means of blocking diodes to provide isolation between said switch network means and said output means.

7. In Teletype communication systems, apparatus for converting Baudot-coded messages into Huffman-coded messages for transmission thereof and for converting said Huffman-coded messages back into Baudot-coded messages after reception thereof and comprising;

at a Teletype transmitter station:

parallel input means for reading Baudot-coded messages to be transmitted and for producing a unique, digital output signal for each different input character read thereby;

means for producing a complementary, binary digital output pair;

switch means responsive to said output signal to couple said digital output pair to one of 32 output terminal pairs;

means for coupling said digital output pair from said output terminal pair simultaneously to selectively predetermined ones of 10, parallel signal paths;

means for sequentially recording the outputs of said signal paths wherein the serial digital sequence recorded represents a Huffman-coded output character equivalent to the input character read by said input means;

means for transmitting said serial, digital sequence; at a receiver station:

series, input means for reading said transmitted sequence and for producing a unique, digital output signal for each different input character read thereby;

means for producing a binary digital output;

switch means responsive to said output signal to couple said digital output to one of 32, output terminals of said switch means,

means for coupling said digital output from said output terminal simultaneously to selectively predetermined ones of five, parallel signal paths; and,

means for recording simultaneously the outputs of said signal paths wherein the parallel, five-place digital word recorded represents a Baudot-coded output character equivalent to the input character read by said input means.

* * * * *