United States Patent [19]

Curtiss et al.

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[54] HIGH SPEED PRINTER

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[21] Appl. No.: **952,002**

[22] Filed: **Oct. 16, 1978**

Related U.S. Patent Documents

Reissue of:

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Issued: **Mar. 5, 1974**
Appl. No.: **876,770**
Filed: **Nov. 14, 1969**

[51] **Int. Cl.**[3] **B41J 1/20**

[52] **U.S. Cl.** **101/93.14**; 101/93.09

[58] **Field of Search** 101/96, 1, 93.14, 93.15–93.17, 101/93.29–93.34, 93.48, 111; 317/137

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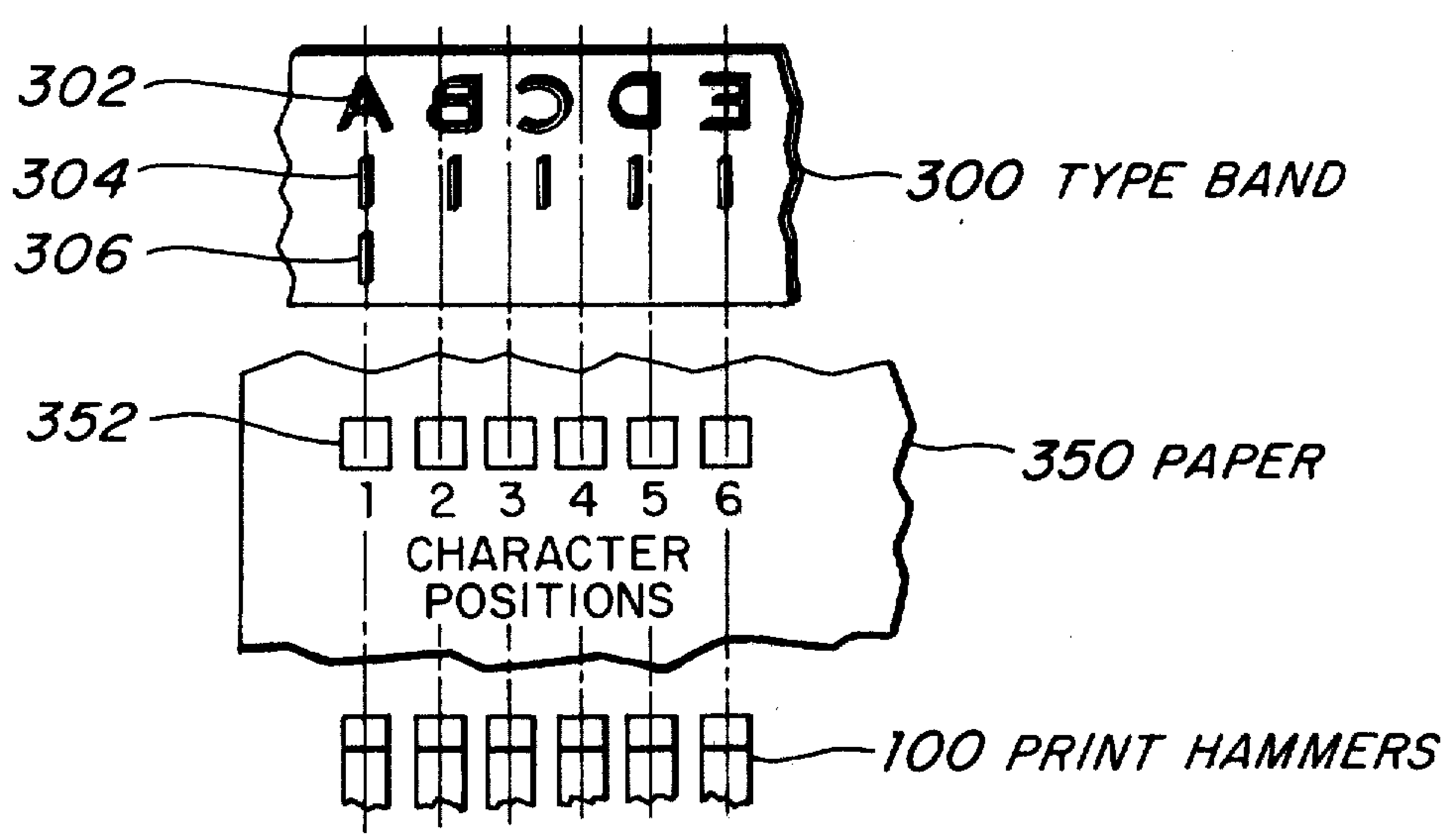
Primary Examiner—Edward M. Coven
Attorney, Agent, or Firm—Daniel M. Rosen

[57] **ABSTRACT**

A high speed line printer having a number of sets of hammers; one hammer for each character position defining a line of print, which coact with a moving type band. Each hammer time shares one of a number of drive circuits with others of the hammers in a set. A line may be printed in the time that a type font on the band moves past any particular character position.

19 Claims, 18 Drawing Figures



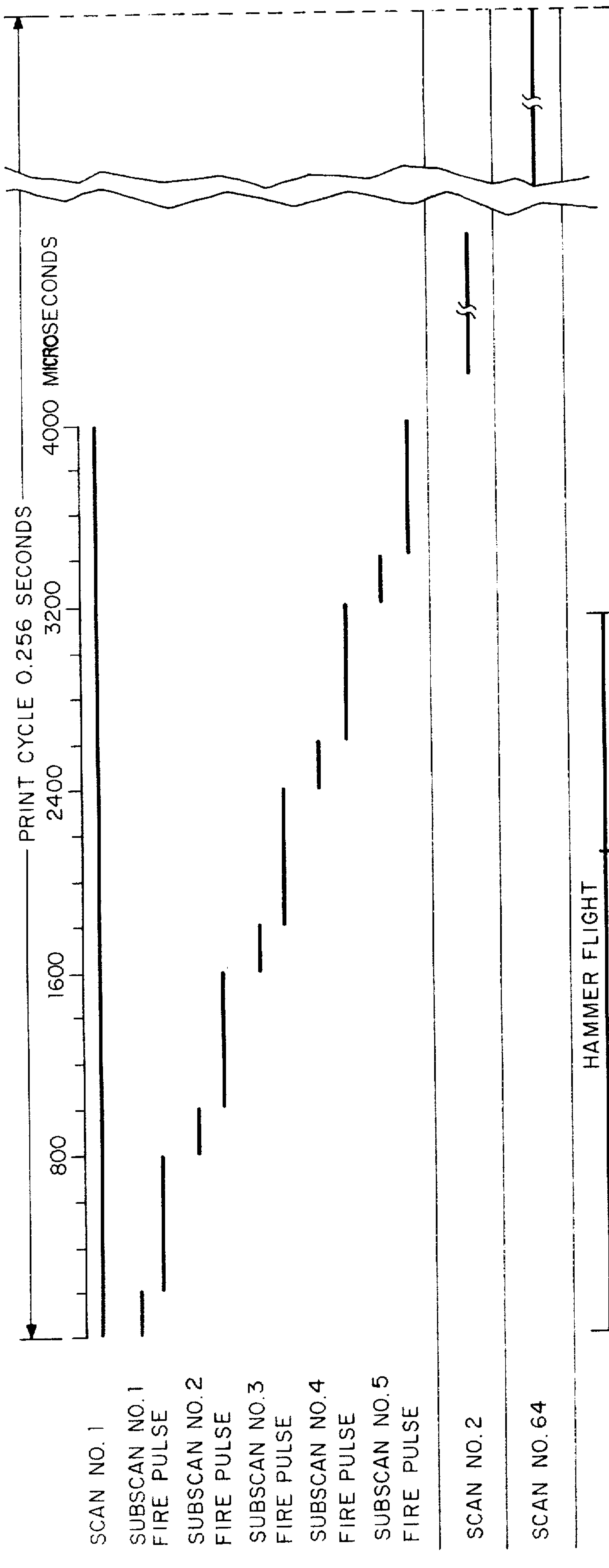

PRINT CYCLE 0.256 SECONDS
4000 MICROSECONDS
3200
2400
1600
800
SCAN NO. 1
SUBSCAN NO. 1 FIRE PULSE
SUBSCAN NO. 2 FIRE PULSE
SUBSCAN NO. 3 FIRE PULSE
SUBSCAN NO. 4 FIRE PULSE
SUBSCAN NO. 5 FIRE PULSE
SCAN NO. 2
SCAN NO. 64
HAMMER FLIGHT
IMPACT

FIG. 1

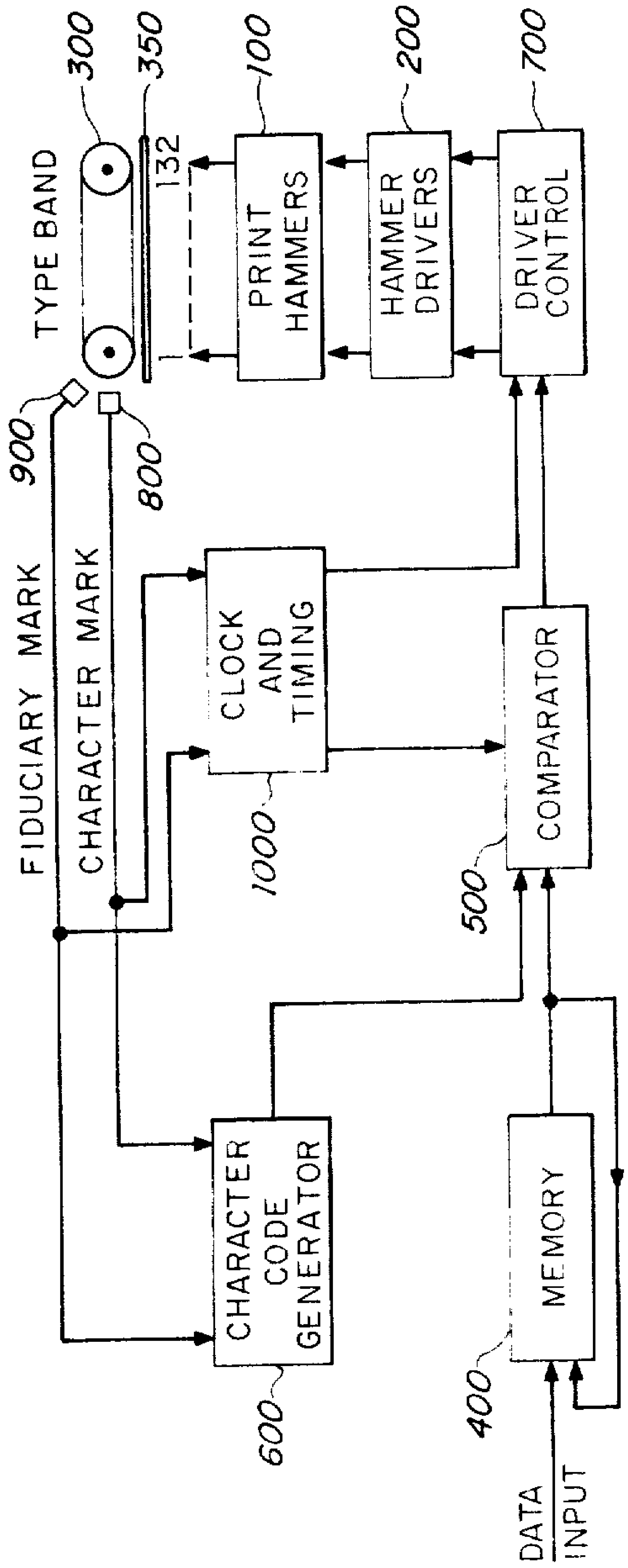

TYPE BAND
300
350
132
100
200
700
PRINT HAMMERS
HAMMER DRIVERS
DRIVER CONTROL
900
800
FIDUCIARY MARK
CHARACTER MARK
CLOCK AND TIMING
1000
COMPARATOR
500
CHARACTER CODE GENERATOR
600
MEMORY
400
DATA INPUT

FIG. 2

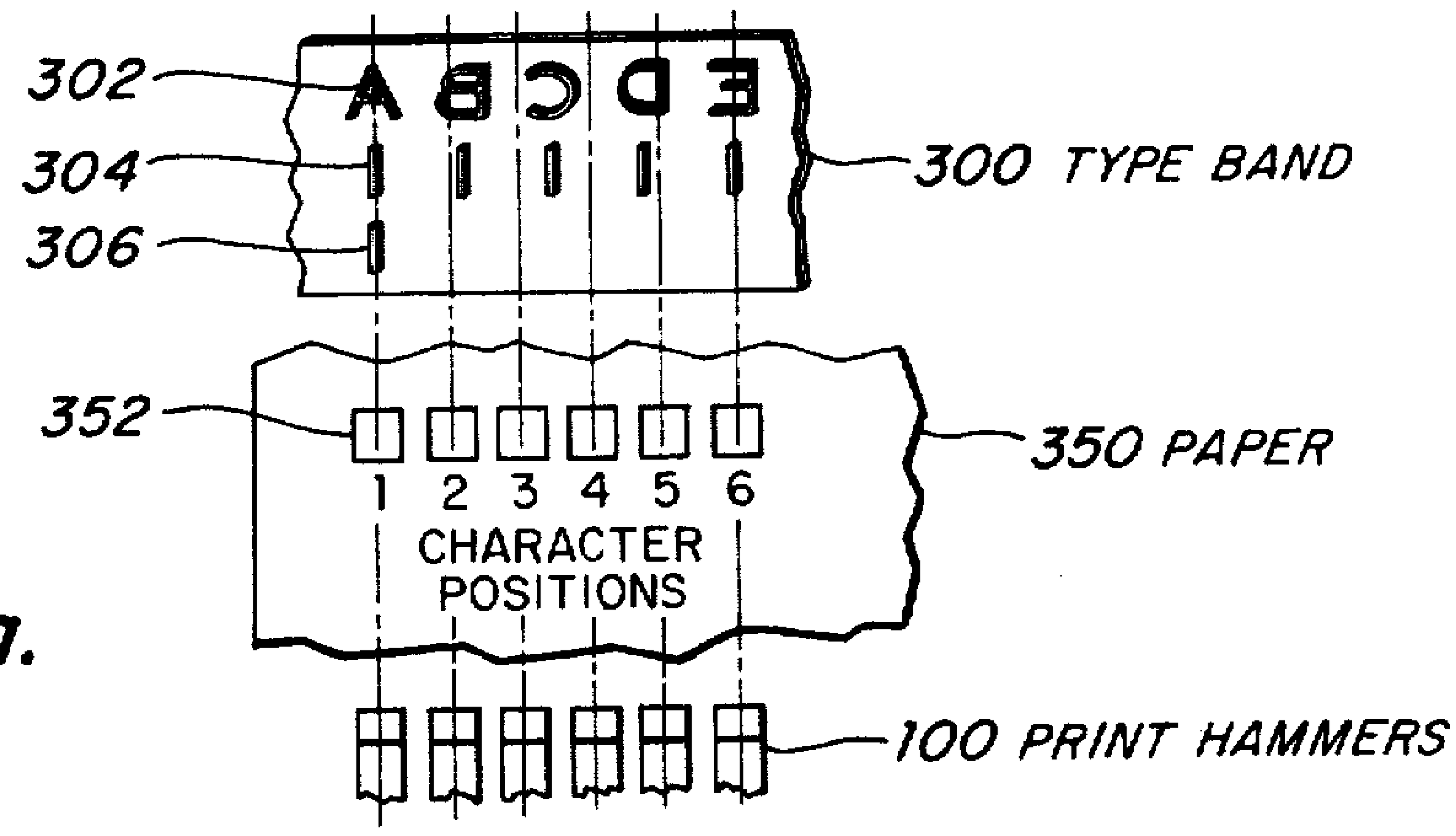


FIG. 3a.

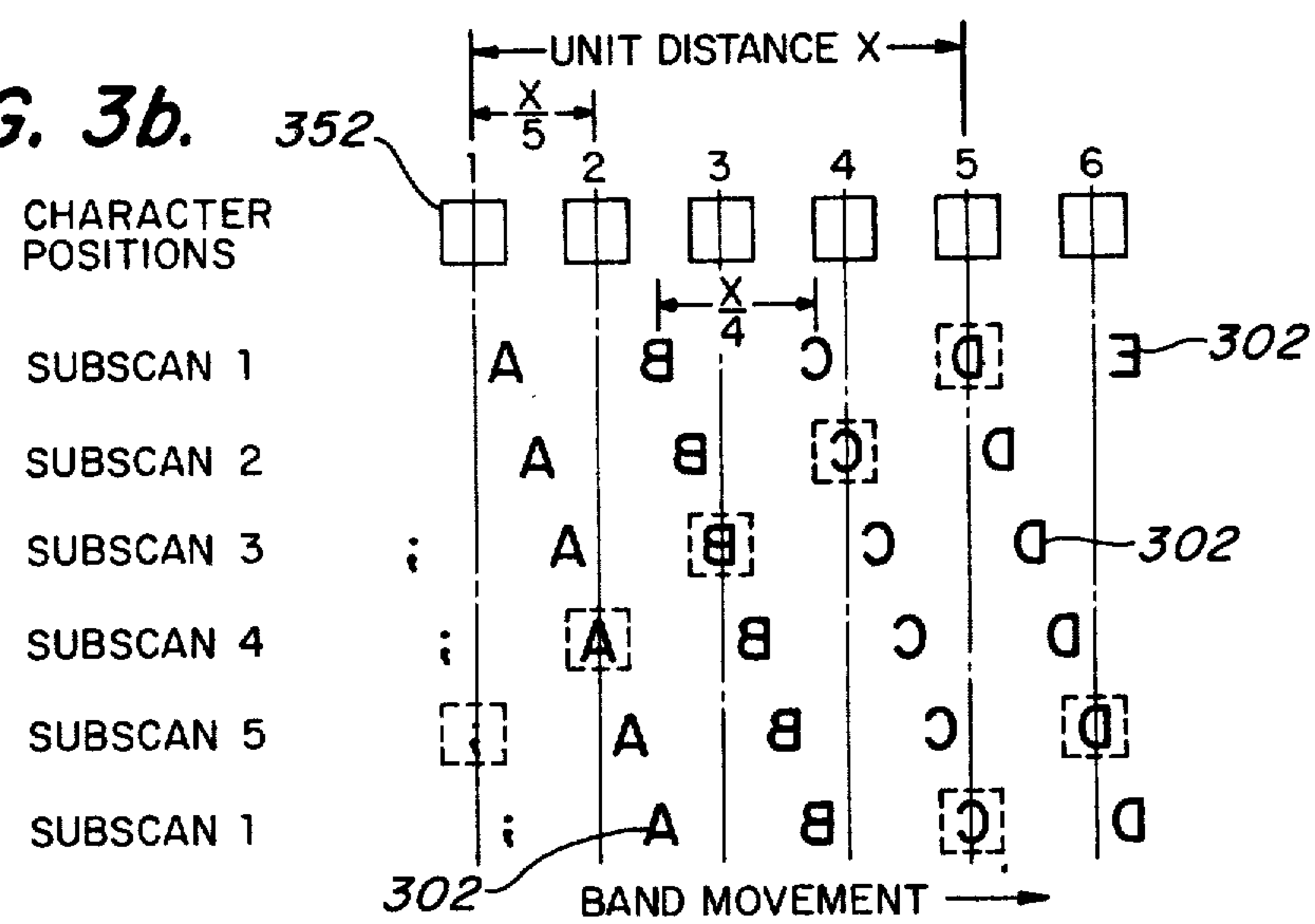


FIG. 3b.

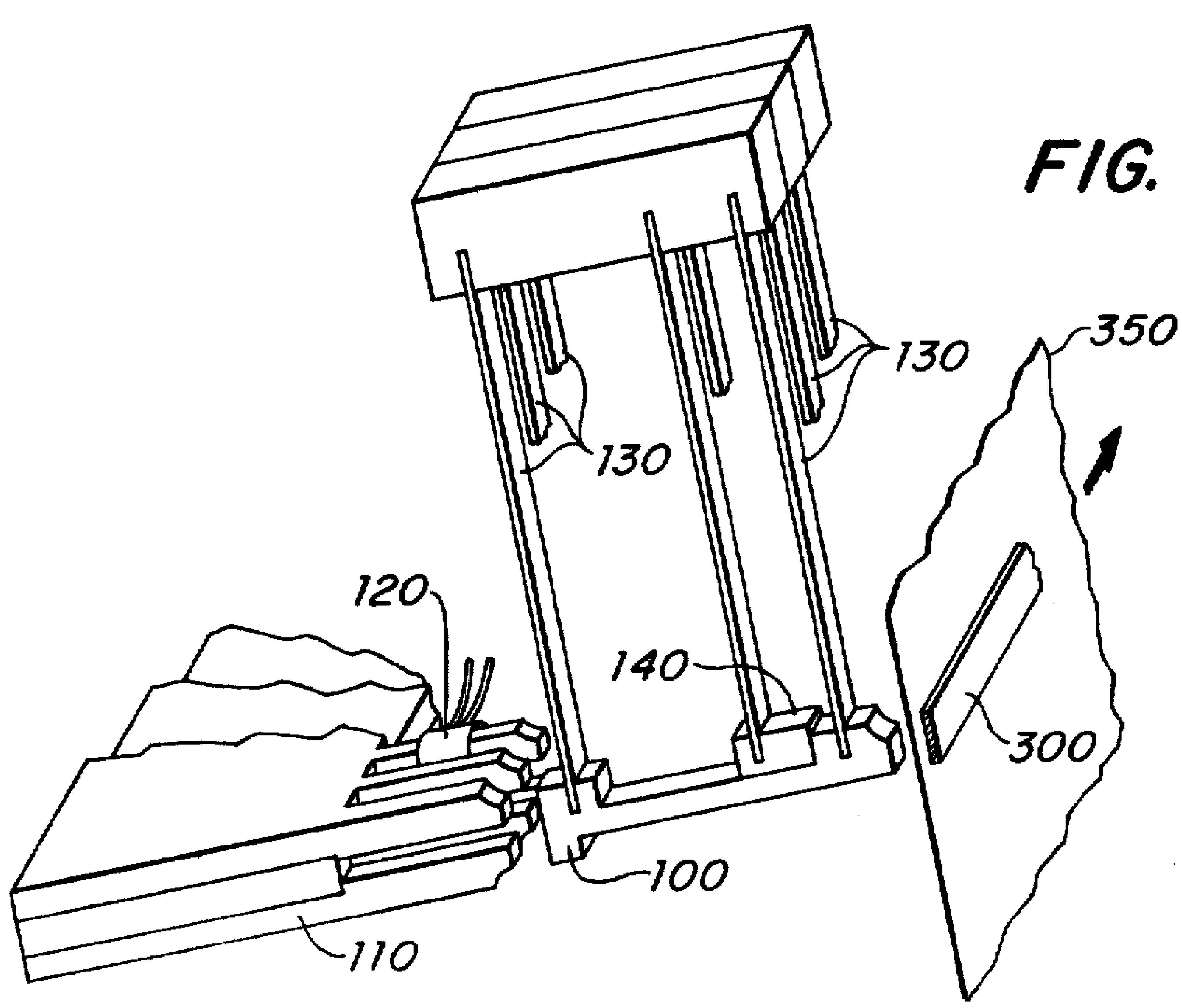
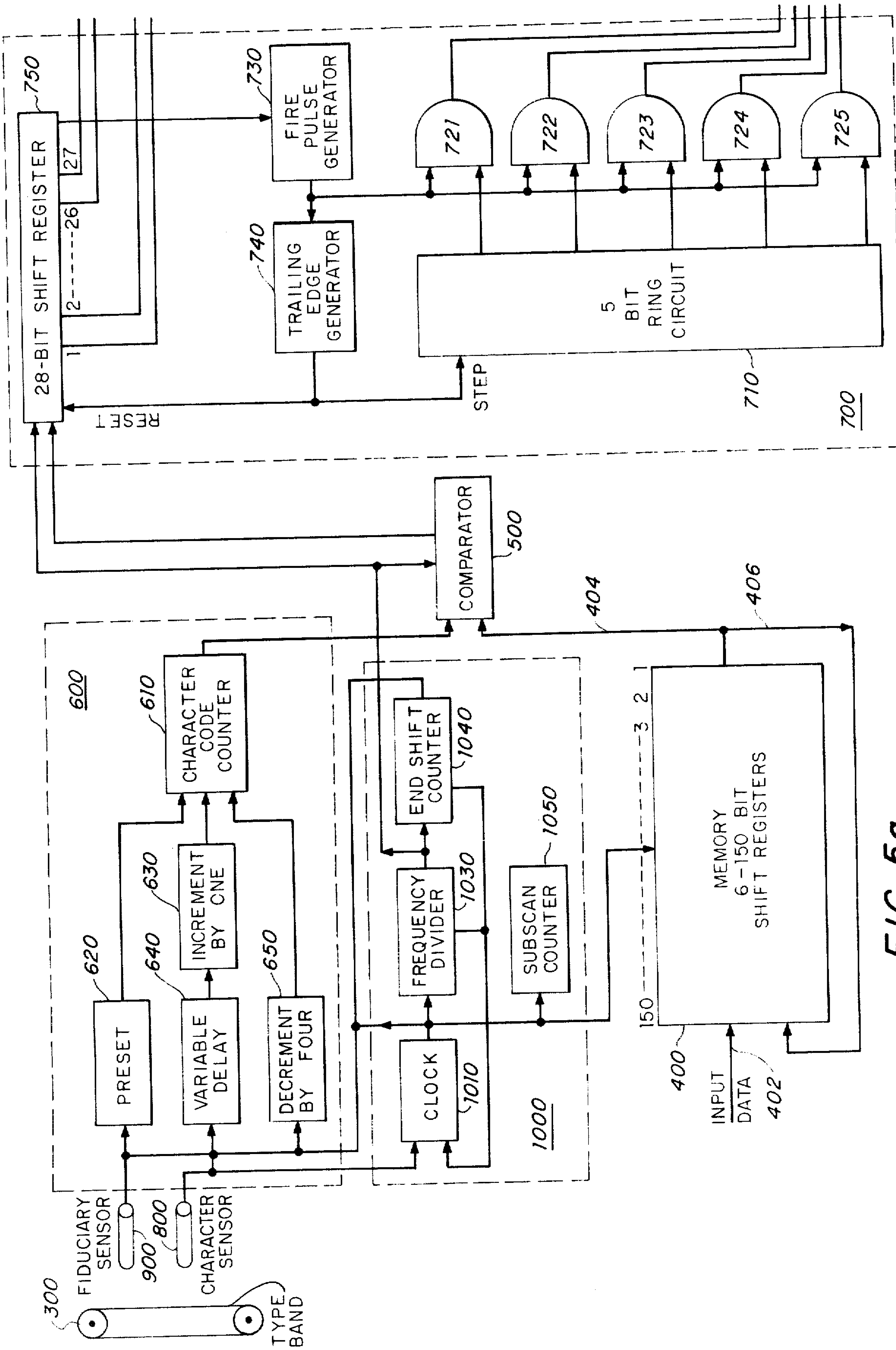


FIG. 4.



28-BIT SHIFT REGISTER
750
27
26
2
1
RESET
FIRE PULSE GENERATOR
730
TRAILING EDGE GENERATOR
740
721
722
723
724
725
5 BIT RING CIRCUIT
710
STEP
700
COMPARATOR
500
404
406
600
CHARACTER CODE COUNTER
610
PRESET
620
INCREMENT BY ONE
630
VARIABLE DELAY
640
DECREMENT BY FOUR
650
END SHIFT COUNTER
1040
FREQUENCY DIVIDER
1030
SUBSCAN COUNTER
1050
CLOCK
1010
1000
MEMORY 6-150 BIT SHIFT REGISTERS
400
150
3
2
1
INPUT DATA
402
FIDUCIARY SENSOR
900
800
CHARACTER SENSOR
300
TYPE BAND

FIG 5a

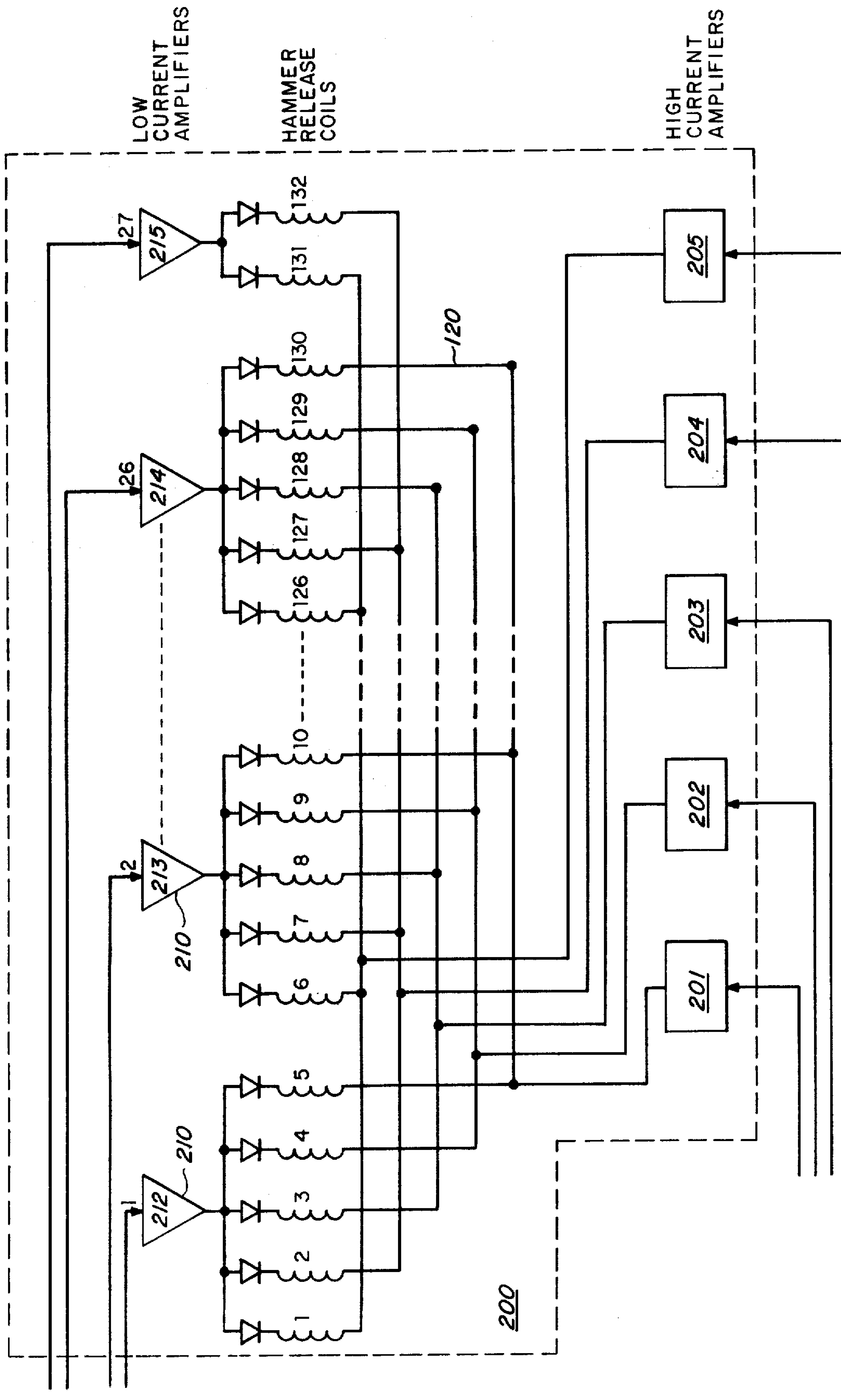

LOW CURRENT AMPLIFIERS
HAMMER RELEASE COILS
HIGH CURRENT AMPLIFIERS
27
215
26
214
2
213
1
212
210
132
131
130
129
128
127
126
10
9
8
7
6
5
4
3
2
1
120
205
204
203
202
201
200

FIG. 5b


DUMMY SHIFTS
20 16 12 08 04 00
(6X-4)+1
01 (6X-4)+1
02
03
04 (6X-4)-4+1
CHARACTER AND HAMMER POSITIONS
X
Y
CHARACTER

FIG. 6b.

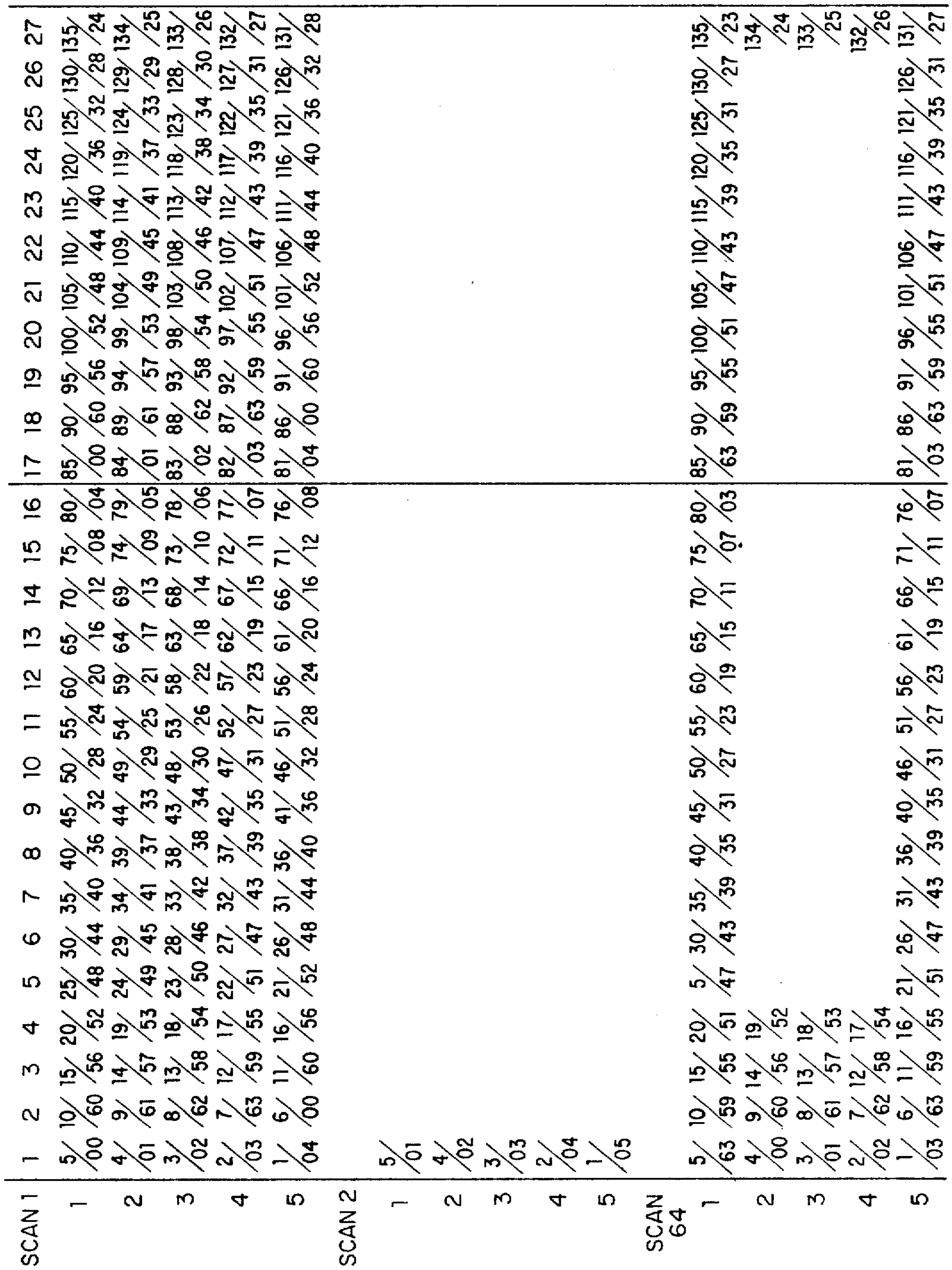

SCAN 1
SCAN 2
SCAN 64

FIG. 6a.

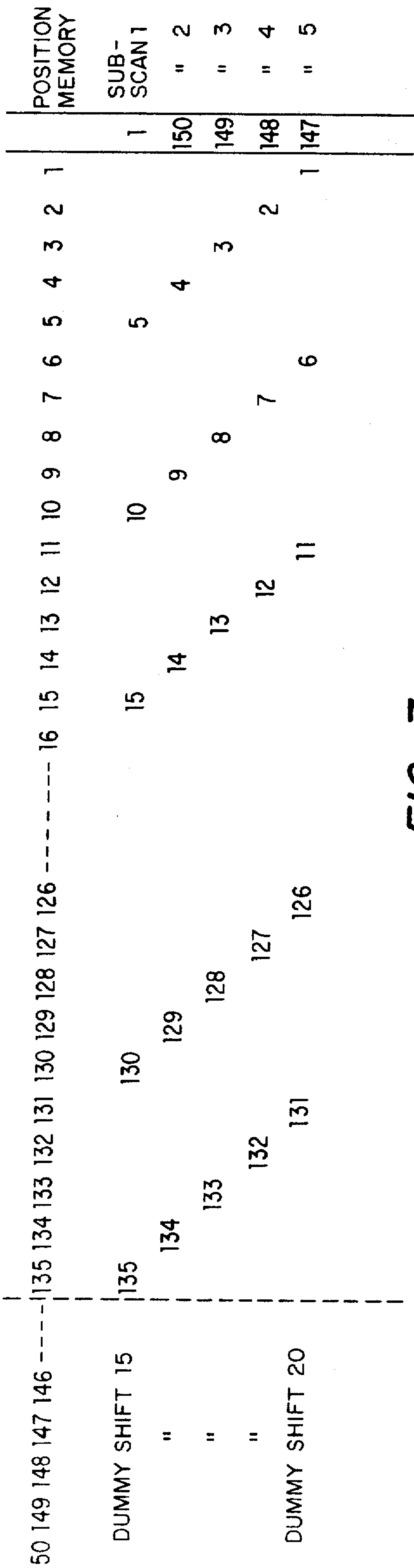

POSITION MEMORY
SUB-SCAN 1
DUMMY SHIFT 15
DUMMY SHIFT 20

FIG. 7.

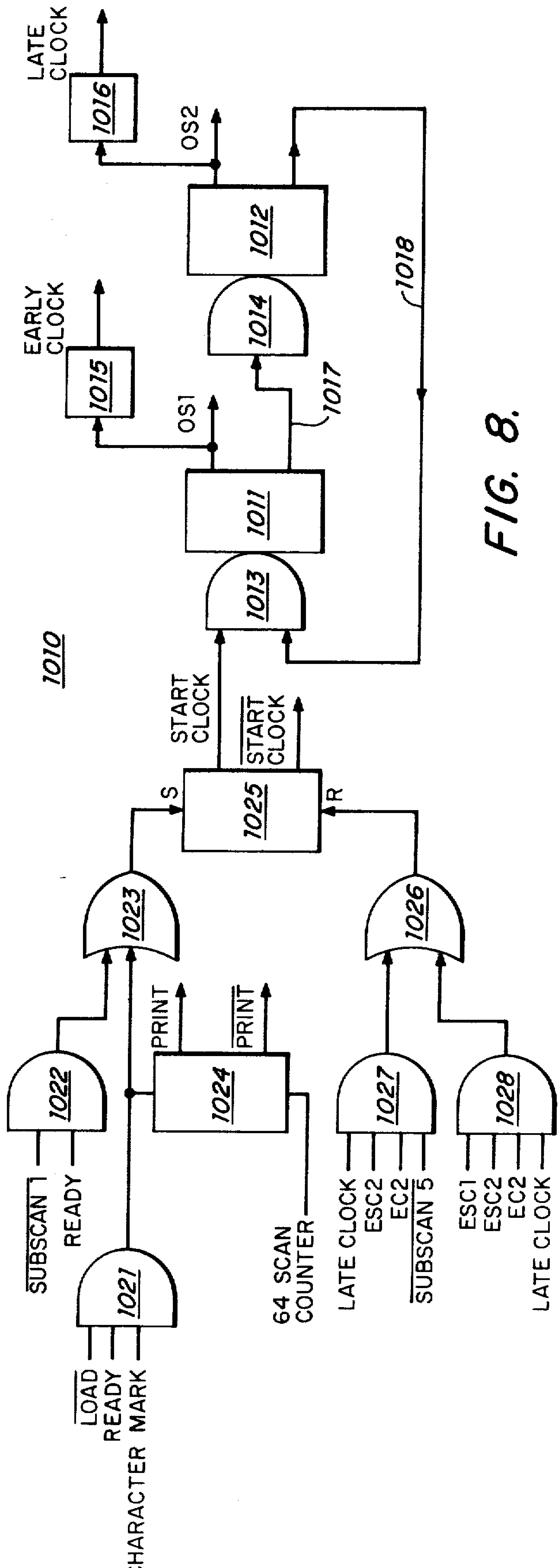

1010
LATE CLOCK
EARLY CLOCK
OS1
OS2
1015
1016
1011
1012
1013
1014
1017
1018
START CLOCK
START CLOCK
S
R
1025
1023
1026
1022
1024
1021
1027
1028
PRINT
PRINT
SUBSCAN 1
READY
LOAD
READY
CHARACTER MARK
64 SCAN COUNTER
LATE CLOCK
ESC2
EC2
SUBSCAN 5
ESC1
ESC2
EC2
LATE CLOCK

FIG. 8.

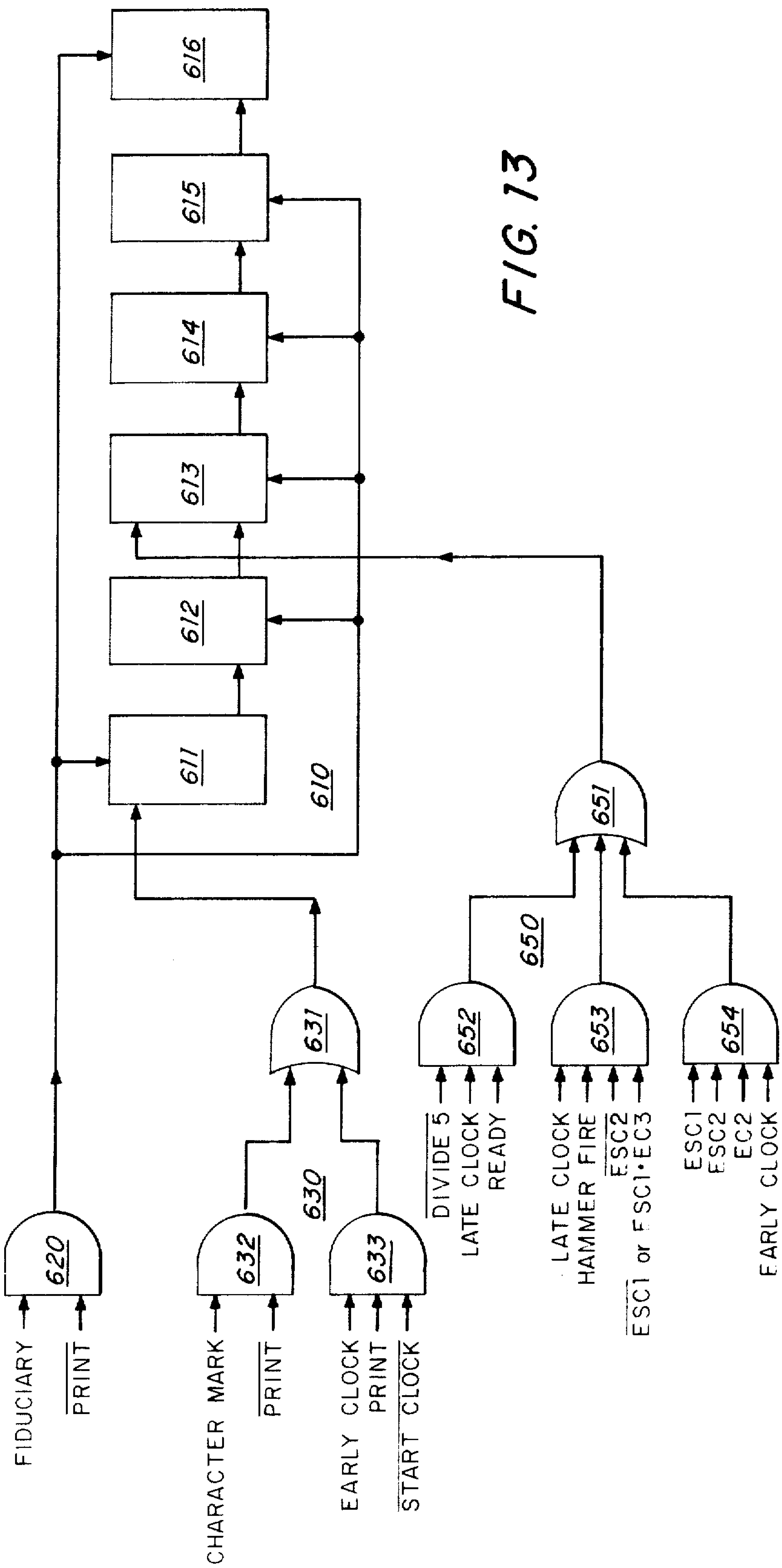

616
615
614
613
612
611
610
620
FIDUCIARY
PRINT
631
630
632
CHARACTER MARK
PRINT
633
EARLY CLOCK
PRINT
START CLOCK
651
650
652
DIVIDE 5
LATE CLOCK
READY
653
LATE CLOCK
HAMMER FIRE
ESC2
ESC1 or ESC1·EC3
654
ESC1
ESC2
EC2
EARLY CLOCK

FIG. 13

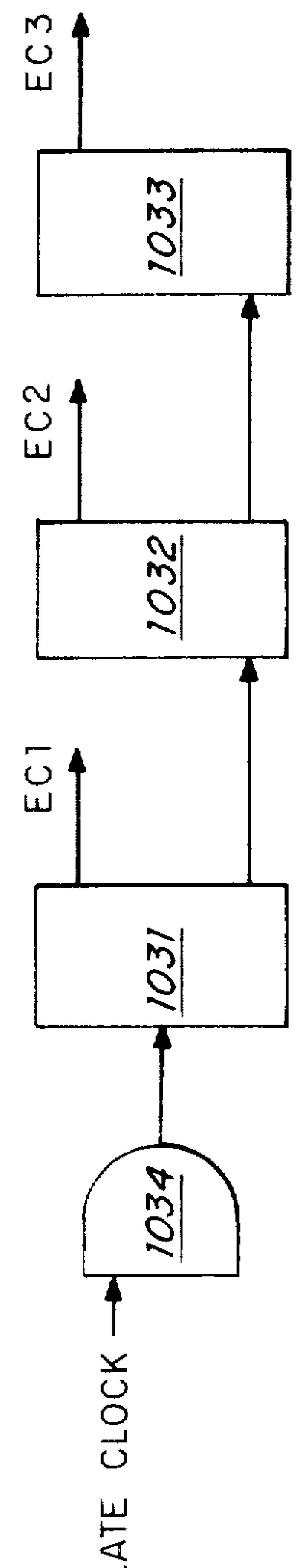

EC3
1033
EC2
1032
1030
EC1
1031
1034
LATE CLOCK

FIG. 9

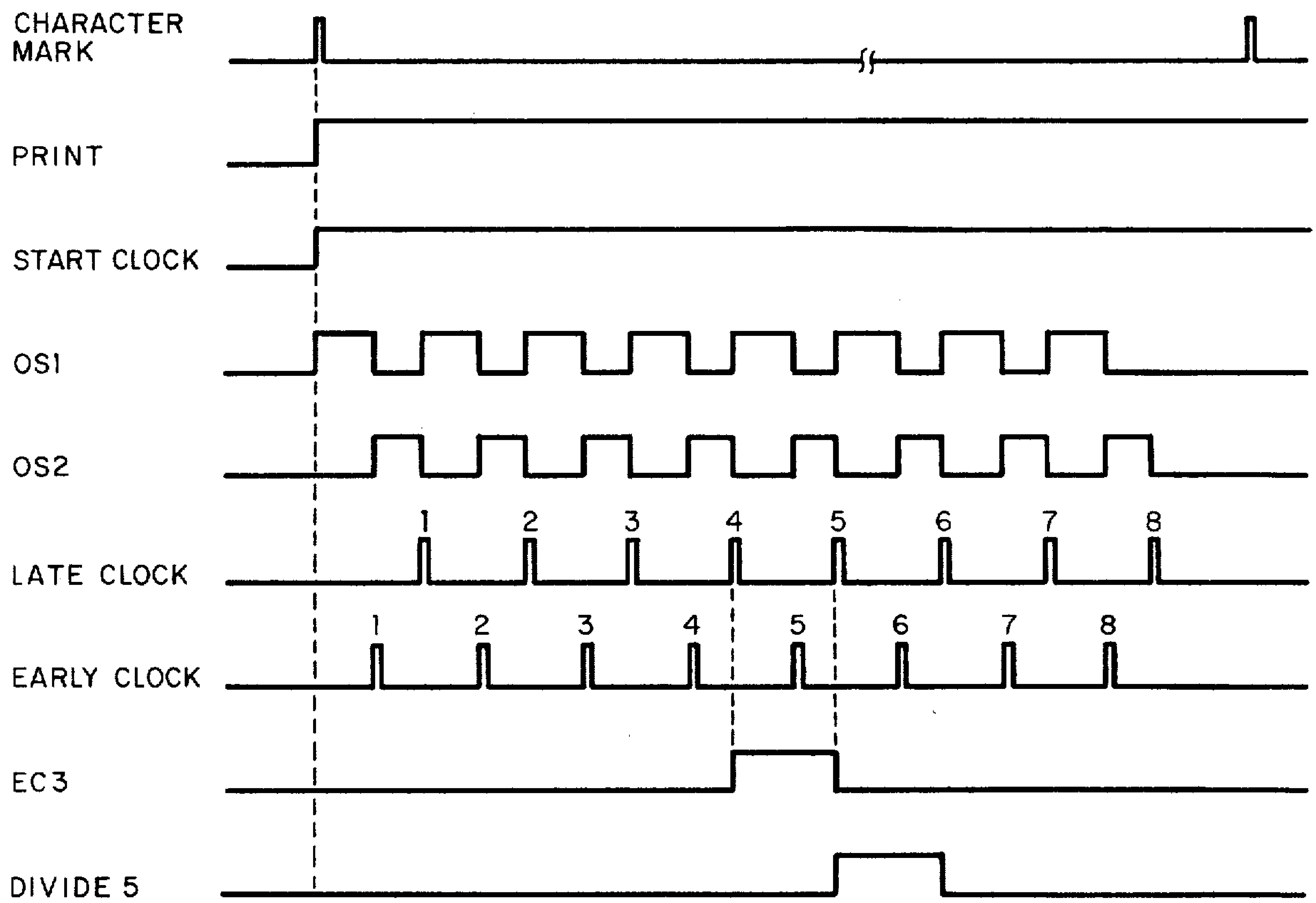


FIG. 12

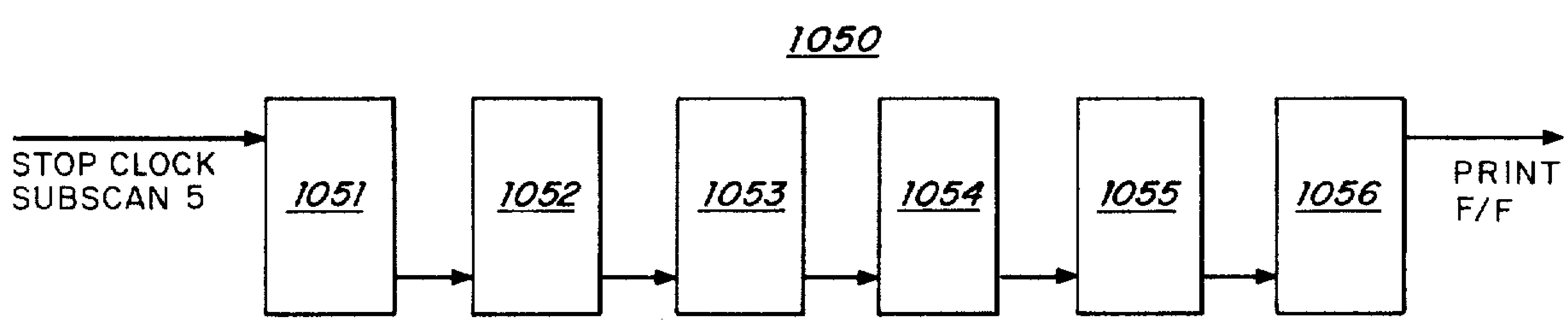


FIG. 11

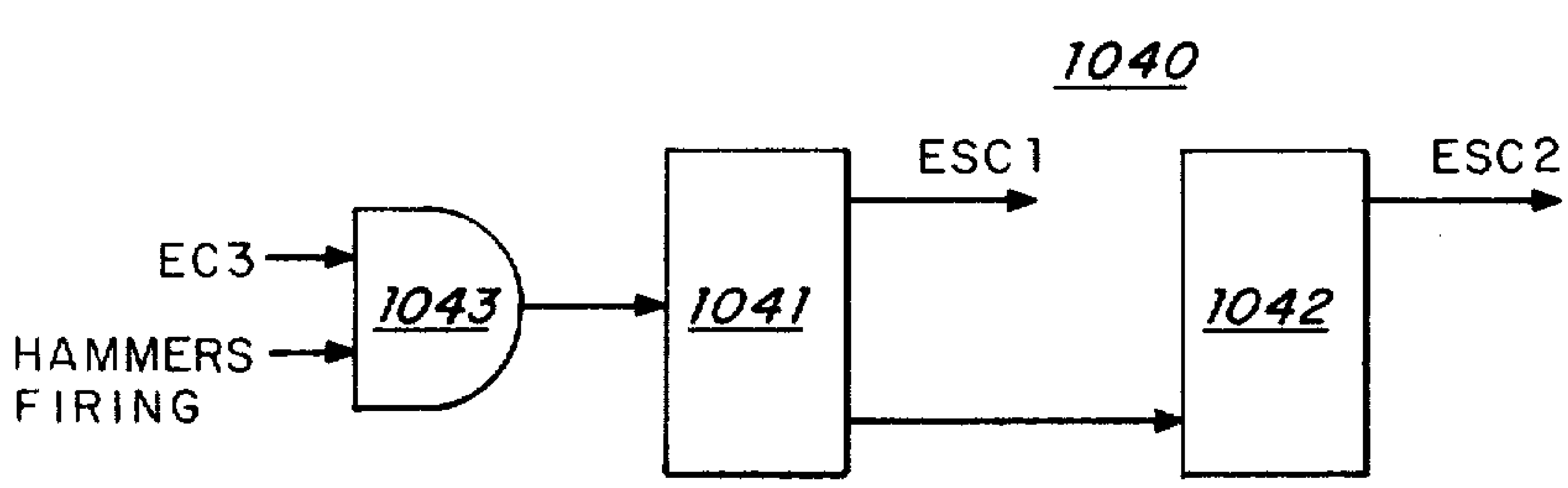


FIG. 10

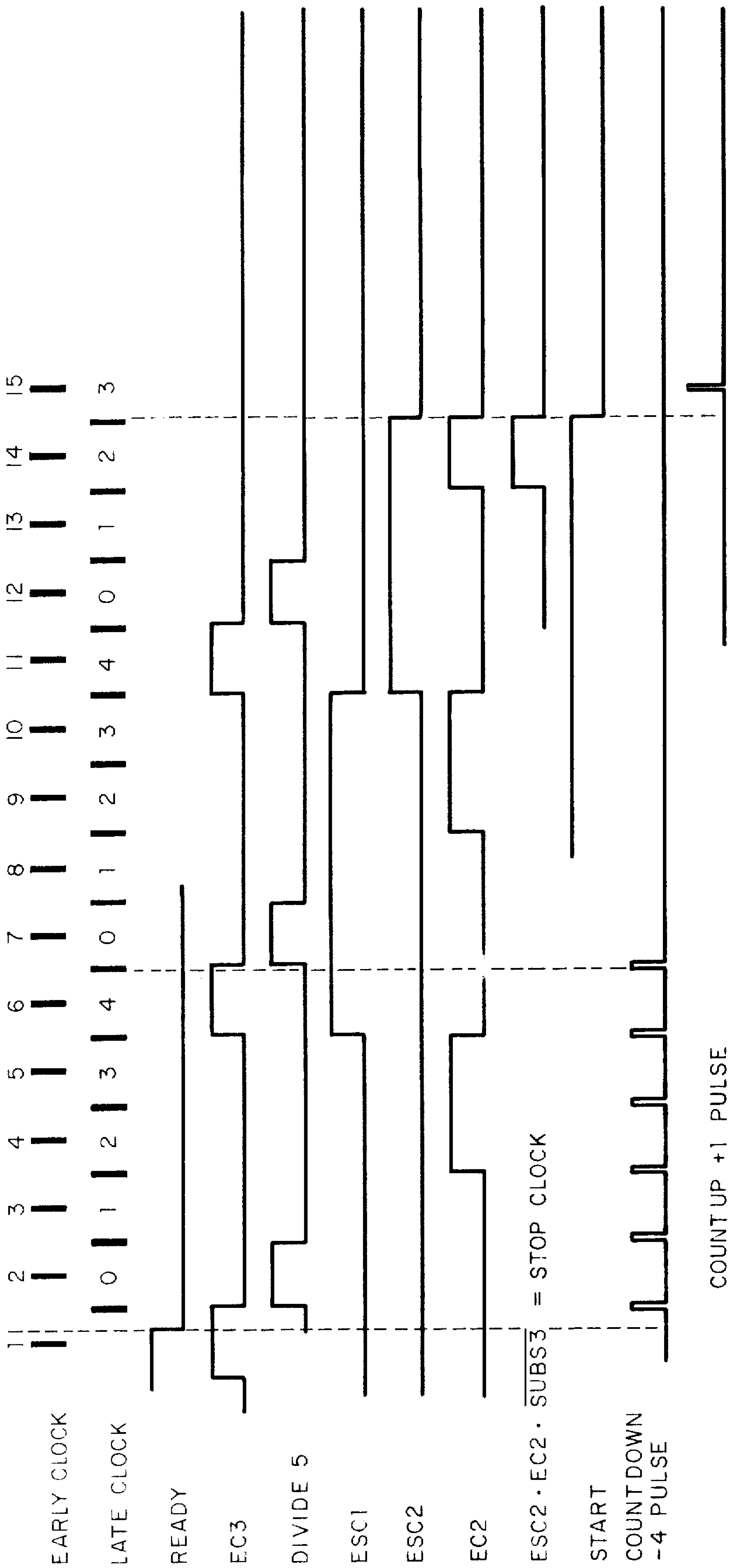

EARLY CLOCK
LATE CLOCK
READY
EC3
DIVIDE 5
ESC1
ESC2
EC2
ESC2 · EC2 · $\overline{SUBS3}$ = STOP CLOCK
START
COUNT DOWN -4 PULSE
COUNT UP +1 PULSE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0 1 2 3 4 0 1 2 3 4 0 1 2 3

FIG. 14

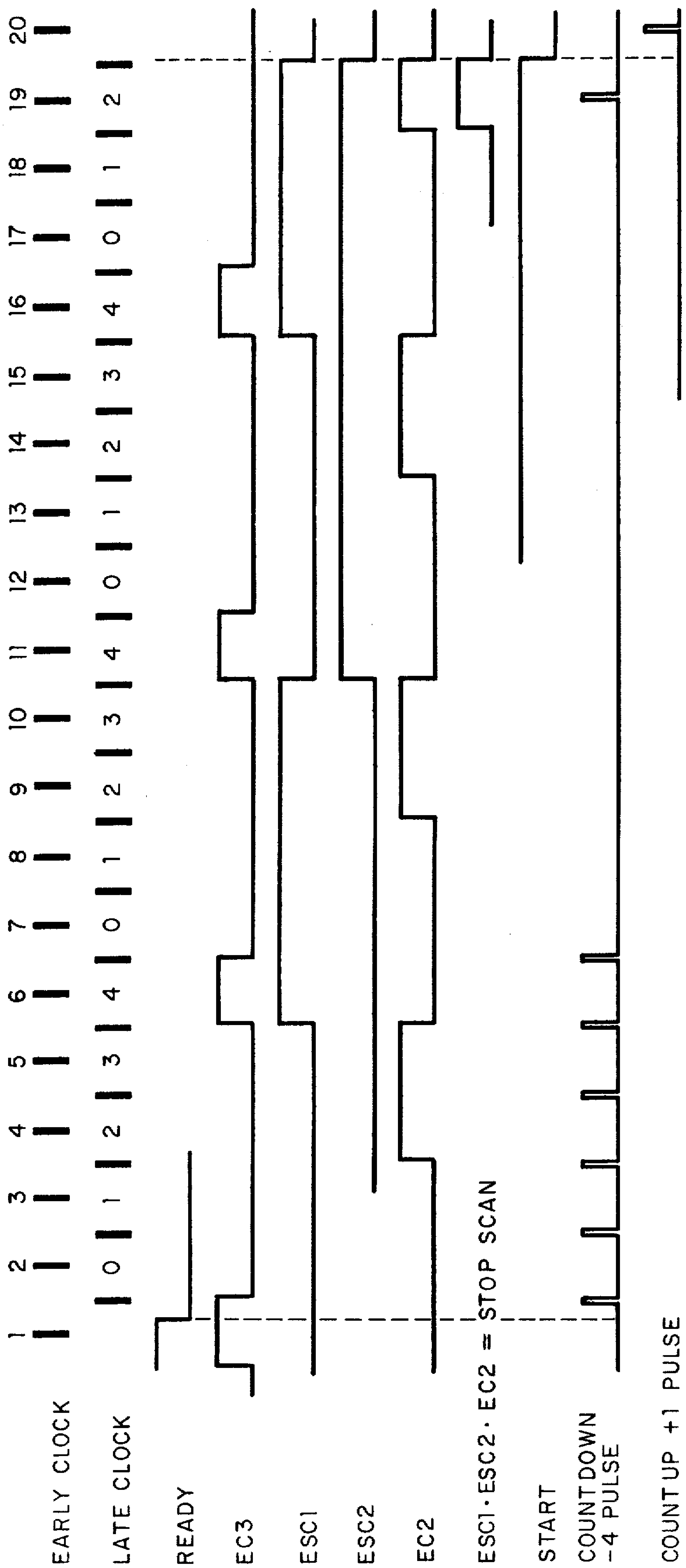

EARLY CLOCK
LATE CLOCK
READY
EC3
ESC1
ESC2
EC2
ESC1·ESC2·EC2 = STOP SCAN
START
COUNT DOWN -4 PULSE
COUNT UP +1 PULSE

FIG. 15

HIGH SPEED PRINTER

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS REFERENCES TO RELATED APPLICATIONS

The following co-pending applications contain disclosure cross referenced herein:

Ser. No. (NO-101F) filed Sept. 12, 1969, entitled Hammer for Impact Printer, applicant Robert H. Curtiss et al.;

Ser. No. (NO-102F) filed Sept. 12, 1969, entitled Type Carrier, applicant Richard Holzman; and,

Ser. No. (NO-103F) filed Sept. 12, 1969, entitled Transducer, applicant Robert H. Curtiss et al.

All of these applications are assigned to the assignee of this application.

BACKGROUND OF INVENTION

This invention relates to high speed printers and more particularly to such printers employing an endless type carrier coacting with a number of sets of hammers, one hammer for each character position in a line and a hammer driver for each set of hammers, the hammer driver being timed-shared among the hammers of a set.

Impact line printers are characterized by a moving endless print carrier having a number of characters etched, engraved, embossed or otherwise formed on or attached to the carrier surface. The character area of the carrier is designed for coacting with a print hammer at each character position on a line to effect printing on a print medium such as paper. Storage, control and timing circuitry are utilized to actuate a particular hammer at the precise time that a character desired to be printed at a character position is in registration with the position.

Both drum and endless chain printers are common in the prior art. Drum printers employ a drum with a matrix of print characters, constantly rotating about its horizontal axis, and having identical type characters in any particular row. Each column defines a complete type font.

Chain printers employ an endless band having affixed thereto individual type elements. The band moves horizontally across the print medium proximate to the line to be printed. Usually a number of type fonts are presented successively along the chain.

The human eye is sensitive to vertical misalignment but relatively insensitive to horizontal misregistration. Drum type printers are sensitive to vertical misalignment, expensive to manufacture, assemble and maintain.

In chain printers typically, links of the type elements readily loosen, and further the band will often stretch or buckle.

Hammer firing must be precisely timed in impact printers to prevent ghosting, smudging or misregistration of printed characters. Therefore, hammer drive circuits must deliver extremely accurate actuation pulses, precise in rise time, duration and magnitude. Further, such pulses be most accurately timed to actuate the hammer exactly when printing is required.

The type of hammer which generally has been used is an electromagnetically operated device which is normally in a rest position and upon the receipt of an actuation pulse is moved from rest to a position of impact. The hammer forces the paper and type ribbon against the type character. High power levels are necessary to impart energy to the hammer during a substantial portion of hammer flight time.

If the printer is to operate at speeds compatible with contemporary computers, a number of hammers must be fired simultaneously or in rapid succession. This requires power supplies having high energy storage and quick recovery time. Such supplies are extremely costly, large and heavy.

Numerous attempts have been made to reduce the cost of printers by time-sharing hammers and/or hammer drive circuits. However, these attempts have resulted in a decrease in speed of operation, an increase in the capacity of the power supply and an increase in the complexity and capacity of the control, timing and storage circuitry.

For example, if hammer drivers are time-shared, once the drivers have been gated to fire at certain character positions, and complete their firing cycle, other characters to be printed have already passed their character position and printing must await the next appearance of the character. If four hammers share a single driver, four cycles of type font may occur before completing a line of type.

In some prior art systems, the type font has been displaced slightly so that characters arrive at various positions in timed sequence. However, hammer actuation pulses must be delivered so rapidly and have such high energy levels, that power supplies must be very large to recharge in time for the next firing cycle, heat dissipation and burn out becomes a problem, and false actuation of hammers often occurs.

Other systems have included shifting type bars, shifting paper carriers and like mechanical systems. These arrangements are limited by the low speed of operation of the mechanical devices employed.

SUMMARY OF INVENTION

The present invention provides the advantages of high-speed, reduced size and cost of an impact printer without suffering from the disadvantages mentioned supra and other disadvantages of prior art devices.

An object of the invention is to provide an improved printer.

A further object is to provide an improved printer employing fewer drive circuits than prior art printers while maintaining and minimizing the total time for a printing cycle.

Yet another object is to provide such a printer with a decrease in power supply requirements.

A further object is to provide an improved printer while decreasing the size and reducing the cost of the system.

The invention features a high speed line printer with reduced complexity, particularly in the area of the hammer drive and control circuitry. To this end a novel combination of elements is employed, while effecting substantial reductions in cost, size and power requirements as well as substantial increases in reliability. At the same time, the speed of operation and print quality of prior art devices are maintained. This is accomplished by a unique combination of type carrier, hammers, and hammer drive control and time circuits. The type carrier is constantly moving and characters thereon are spaced from one another a distance greater than the spacing between character positions on the print medium. The print hammers are magnetically restrained in the cocked position by a permanent magnet opposing a mechanical bias. This bias, upon release, causes the hammers to impact the print medium and effects printing by co-action between the print medium and the type characters on the font belt. Thus, the energy to drive the hammers is in the nature of kinetic energy stored when the hammers are cocked rather than energy transferred from drive pulses as in the case of solenoid operated hammers. Therefore, the hammers are released by low energy, extremely short duration current pulses which set up magnetic fields in opposition to the fields caused by the permanent magnet, releasing the hammers into flight. The pulse time is a fraction of hammer flight time.

Since the hammer driver pulses may be short in duration and of low energy, hammer drivers may be time-shared by a number of hammers in a time sequence equivalent to the sequential registration of type characters on the band with characters positions, thereby substantially reducing the total number of drivers necessary to fire the hammers.

DISCLOSURE OF PREFERRED EMBODIMENTS

Other objects, features and advantages will occur from the following description of preferred embodiments and the accompanying drawings, in which:

FIG. **1** is a chart depicting timing of major events in a print cycle;

FIG. **2** is a general block diagram of a printer system in accordance with the invention;

FIG. **3a** is a partial front view of a type carrier, print medium and hammers employed in the printer system of FIG. **2**;

FIG. **3b** shows in schematic form the relative movement of the type band and character position during a number of subscans;

FIG. **4** shows a portion of a few of the hammers and a portion of the permanent magnet associated with the hammers;

FIGS. **5a** and **5b** together show a more detailed block diagram of the embodiment of FIG. **2**;

FIG. **6a** is a chart showing the contents of the character code counter during various scans and subscans of the print phase;

FIG. **6b** depicts the meaning of the chart of FIG. **6a**;

FIG. **7** is a chart depicting the shifting of data in the memory during any single scan of the print phase;

FIG. **8** is a logic diagram of the clock circuit and associated logic;

FIG. **9** is a logic diagram of the frequency divider;

FIG. **10** is a logic diagram of the end shift circuit;

FIG. **11** is a logic diagram of the scan counter;

FIG. **12** is a timing diagram showing the relationship of various pulses developed in the circuits of FIGS. **8** to **11**;

FIG. **13** is a logic diagram of the character code generator.

FIG. **14** is a diagram illustrating the timing of various pulses of FIGS. **8** to **11** and **13**, after completion of subscans **1** to **4**; and,

FIG. **15** is a diagram illustrating the timing of various pulses of FIGS. **8** to **11** and **13**, after completion of subscan **5**.

A printer system has three functional phases or cycles of operation: data load; print; and bail and paper feed. During the data load phase, the data desired to be printed on a single line is fed into a buffer memory from the data source. During the print phase, printing occurs. During the bail and paper feed phase, the paper and ribbon are advanced and the print hammers are bailed or cocked. Both the data load and bail and paper feed phases may be accomplished simultaneously. Since the data load, and bail and paper feed phases form no part of the inventive concept, no additional mention of either phase is made herein.

A print phase, FIG. **1**, is 0.256 seconds in duration and consists of 64 scans; each scan is approximately 4 milliseconds. During each scan, five subscans of 200 microseconds are completed. Each subscan is followed by a 600 microsecond firing pulse period.

Type characters on the carrier are staggered relative to character position such that during the firing pulse period following any particular subscan, only one-fifth of the type characters on the band are in registration with particular character positions on the print media. The subscan is the time period used for comparison of particular type character codes, hereinafter referred to as character codes, those in registration during the succeeding firing pulse period, with codes indicative of characters desired to be printed in these positions, hereinafter referred to as data codes. Hence, during any one scan, five subscans, a character code is compared to the data code for each position. The type font employed in this embodiment is a 64 character code. Thus, 64 scans are necessary to compare each character code in a font with the data code for each character position.

Hammer flight time is also shown in FIG. **1**, the time from release of the hammer from the cocked position to impact on the paper and rebound to a rest position. This time is approximately 3 milliseconds or one-fourth of a complete scan. It is seen from FIG. **1** that a subscan begins long before hammers released by prior firing pulses come to rest.

Typically, in prior art printers, hammer firing pulses must be of a duration of approximately 1,300 miliseconds, in excess of twice as long as firing pulses utilized in the present invention. Because of the short pulse duration of the pulse used in the invention system, drivers may be time shared effectively and efficiently.

FIG. **2** depicts a functional block diagram of a printer embodiment utilizing the present invention. 132 print hammers **100**, one for each character position in a line of print on a print carrier medium such as paper **350**, time-share a set of 27 hammer drivers or hammer release means **200**. The hammers coact with a moving type carrier or type band and an inked type ribbon, not shown in the interests of clarity, to produce a line of print. Data to be printed is fed into a regenerative memory **400** from a data source such as a computer, not shown, which memory feeds a comparator **500**. A character code generator **600** also feeds comparator **500**, the output of which is fed to driver control circuit **700**. Marks on the band **300** are sensed by sensors **800** and **900**, the output of which feed clock and timing circuitry **1000** and character code generator **600**.

A line of print consists of 132 character positions, each character position has an associated hammer and every set of five hammers has an associated one of 27 hammer drive circuits. The last set has only two hammers. The type band has six 64 character type fonts, actually 63 characters and one space, a character mark associated with each character and the space, and a fiduciary or font mark associated with each of the six fonts.

A print phase, the time necessary to complete one line of print, is equal to the amount of time it takes a complete type font to pass a character position.

During each subscan, FIG. **1**, the data code representing the character to be printed, stored in memory **400**, is compared in comparator **500** to a character code generated by the character code generator **600**. The character code specifies the type character present at that position during the following firing period. When a match, a favorable comparison, or mismatch, unfavorable comparison, occurs; indications of either condition are stored in the control circuits **700**. During a subscan, 27 comparisons are made, followed by the generation of fire pulses by the drivers **200** then connected to the hammers corresponding to character positions where a match occurred.

The fire pulse duration, FIG. **1**, is less than one quarter of the average hammer flight time. Hence, almost three subscans are completed prior to completion of flight of hammers set in motion during preceding fire pulse periods.

During the first subscan, the data code representing characters to be printed in character positions **5**, **10**, **15** . . . **130** is compared to the character code indicative of type character arriving at these positions, and each of the 27 driver circuits **200** are connected to each of the hammers **100** corresponding to those positions. Only those drivers associated with a match are enabled by the control circuits **700** during a firing period to follow any particular subscan.

During the second subscan, the data code for data to be printed in character positions **4**, **9**, **14** . . . **129** is compared to the character code for type characters arriving thereat during the associated firing period. In like manner, during subscans **3**, **4** and **5**, the remaining character codes are compared to the data codes to be printed. Thus, the 27 drivers **200** are time shared.

Timing initiation results from a character mark on the band being sensed by character sensor **800** and synchronization, by a pulse sensed by fiduciary sensor **900**. The pulse starts the clock **1000**. Synchronization occurs at the start of each of of the sixty-four scans or cycles. During the load and bailing and paper feed phases, the character code generator **600** is set by the receipt of a fiduciary mark signal from sensor **900** and is stepped by a count of one by the receipt of each character mark from sensor **800** thereafter, so that scanning may begin immediately at the commencement of a scanning cycle. If the generator **600** were not kept current with movement of the band, the print phase might be delayed by as mush as 0.256 seconds, the time for movement of a complete font of type on the band past any particular point.

The type band **300**, FIG. 3a, has a row of type characters **302**, a row of character marks **304**, and a row of fiduciary or "start of font" marks **306** formed thereon. A suitable type band is described in copending application Ser. No. 857,507, now abandoned, (NO-102F) filed Sept. 12, 1969, entitled Type Carrier, invented by Richard Holzman and having a common assignee with the present application. In line with the band is a sector of the paper **350** to be printed upon. The rectangles **351** through **355**, shown on the paper designate character positions on the paper. Faces of a few of the print hammers **100** are shown which impact the paper **350** and a ribbon (not shown) forcing paper and ribbon against the band to effct printing. The linear distance between character positions **302** and corresponding hammer positions differs from the distance between type characters **302** on the band **300**.

For each five character positions only four type characters appear. FIG. 3b is a schematic representation showing character positions **352** on the print medium **350** and the type characters **302** on the band **300** moving from left to right during six successive subscans. In the firing pulse period immediately following subscan **1**, type character **302**, "D" is in registration with character position **5**. Likewise, type characters are in registration with positions **10**, **15** . . . **125** and **130** during this subscan. The other character positions do not have type characters in registration at this time. During the firing period following subscan **2**, type characters **302** are in registration with character positions **4**, **9**, **14**, **19** . . . **129** represented by type character "C" in position **4**.

In a similar manner, type characters come into register with each set of 27 character positions during one subscan. After one complete scan, subscan **1** of scan **2**, the next type character in this instance "C" is in registration with position **5**. Thus, during any particular scan a different one of the 64 characters on the band is in registration with each character position, one-fifth of the characters, during any subscan.

In the embodiment shown, a unit distance is the distance between each five character position centers. Four type characters occupy this distance. Thus, each character position is spaced **X/5**. Each type character is spaced by a distance **X/4** from the next and the relative spacing is **(X/4)/(X/5)=4/5**. If each five character positions occupy 0.500 inches, the distance between positions is 0.100 inches; and, each four characters occupy 0.500 inches, the distance between each character is 0.125 inches. Hence the distance that the belt must travel between successive subscans is only 0.125−0.100=0.025 inches. The belt **300** is timed to move this distance every 800 microseconds, the time between successive subscans. The phase-shift between type characters **302** and positions **352** is commonly designated in the art as "doppler." The particular shift described herein is a "**4** out of **5** doppler." Four type characters **302** appear for each five character positions.

It has been found that hammers which are held in a cocked position biased to naturally impact the paper upon release and thereafter settle in a rest position between the impact and cocked positions are most desirable in the practice of the present invention. Release of the hammers may be effected by a short duration, low energy, electrical pulse with relatively wide limitations on rise time and other parameters. By employing this type of hammer, rather than the type mentioned supra in the discussion of the prior art, simplification of the drive circuitry, reduction in size of the power supply, and the ability to time-share drivers without a loss in speed of operation are effected. The usual hammer utilized in high speed printers is solenoid actuated requiring a drive pulse of long duration and high energy which pulse must be extremely precise in all parameters. A suitable hammer for use in the present invention is disclosed in copending application Ser. No. 854,531 (NO-101F) filed Sept. 2, 1969, entitled Hammer for Impact Printer by Robert H. Curtiss, et al., and assigned to the assignee of this application.

Print hammers **100**, FIG. **4**, are magnetically held in a cocked position by a permanent magnet **110**, and are released into flight by a low energy, short duration current supplied by hammer drivers **200**, FIG. **2**, to coils **120** which surround each magnet. This current opposes the magnetic force holding the hammers in place. The hammers **110** are biased by springs **130** to release, impact the paper and force the paper and ribbon (not shown) against the band **300** to print. The hammers **100** rebounding from the paper are damped by a mass **140** which they strike, to prevent ghosting. The hammers **100** come to rest in a position as shown, between the magnetic circuit and the paper. Thus, energy is stored in the hammers **100** while the cocked position to move the hammers rather than supplied by the driver pulse current. The current merely is sufficient to release the hammers.

A suitable type of sensing device for both character mark sensor **800** and fiduciary mark sensor **900** is described in copending patent application Ser. No. 857,506 (NO-103F) filed Sept. 12, 1969, entitled Transducer invented by Robert H. Curtiss and assigned to the assignee of the present invention. Although magnetic sensing of marks is employed in the embodiment shown, it is well within the purview of these skilled in the art to use other sensing systems such as photo-optical sensing.

Each of the characters appearing on the band **300** is designated by a six-bit binary code which code set has been derived from the seven-bit American Standard Code for Information Interchange.

The hammer drive circuits **200**, FIG. **5**, consist of five high current amplifiers, **201** to **205**. Each amplifier is connected to every fifth hammer release coil. High current amplifier **201** is connected to release coils corresponding to character positions and hammers **5**, **10**, **15** . . . **130**. Amplifier **202** is connected to coils in positions **4**, **9**, **14** . . . **129** and amplifier **205** is connected to coils in positions **1**, **6**, **11** . . . **126** and **131**. The other ends of the hammer release coils are connected to a set of 27 low current amplifiers **210**. These amplifiers are each connected to five hammer release coils in sequence. Thus low current amplifier **212** is connected to coils in positions **1**, **2**, **3**, **4** and **5**; amplifier **213** is connected to coils in positions **6**, **7**, **8**, **9**, and **10**; amplifier **214**, the 26th amplifier, is connected to coils in positions **126**, **127**, **128**, **129** and **130** and amplifier **215**, the 27th, is connected to coils in positions **131** and **132**. Not all of the amplifiers **210** and hammer release coils **120** are shown. Each coil **120** has a series diode **121** to prevent the completion of an unwanted current path between adjacent coils.

The hammers **100** are not shown in FIG. **5**, but have been described in conjunction with FIG. **4**. The numbers 1 to 132 associate with the coils corresponding to character positions.

The memory **400** consists of six 150-bit position shift registers. Input from a data source is via input data lines **402** and output **404** is connected to comparator **500**. The memory is regenerative, that is, the output from position **1** is fed back to the input position **150** via feedback lines **406**.

The character code generator **600** has a character counter **610** fed by a preset circuit **620**, an increment-by-one/circuit **630** fed by a variable delay circuit **640**, and a decrement-by-four circuit **650**.

The driver control circuits consist of a five-bit ring counter circuit **710**, five AND gates **721** to **725**, a fire pulse generator 730 feeding the gates, which also feeds a trailing edge detector **740** and a 28-bit shift register **750**.

The clock and timing circuits **1000**, are fed by character mark sensor **800** and fiduciary sensor **900**. The circuits are a clock circuit **1010**, a frequency divider **1030**, which produces a pulse for every fifth clock pulse, and end shift counter **1040** and a subscan counter **1050**. Clock and timing pulses are fed throughout the printer system.

The band is moving during all phases of printer operation. Prior to commencement of the printing phase the character code counter **610** is preset by preset circuit **620** to a predetermined binary count, 100001, the code for the type character "A," each time that a fiduciary mark **306**, FIG. **3**, is sensed by fiduciary sensor **900**. Thereafter, each time a character mark **304** is sensed by character sensor **800**, the counter **610** is incremented by a count of "**1**" by increment-by-one circuitry **630**. As soon as a print cycle begins, the character counter **610** contains the proper count and it is not necessary to wait for a fiduciary mark to appear at a particular character position to set the counter. Thus it is not necessary to await the beginning of a font to start printing. Printing may start with the band **300** in any position.

It takes approximately one-quarter of a second for the band **300** to move a complete font past a character position. Had the counter not been preset by the previous mark **306** as much as one-quarter of a second delay might be incurred at the beginning of a print phase. Further, the counter **610** is reset by a pulse from sensor **900** initiated by each fiduciary mark **306**. This way slight variations in belt speed do not generate cumulative errors. Data in parallel is loaded into shift registers of memory **400**. The data code for the character to be printed in character position **1**, normally occupying the right most position of the shift registers, enters position **150** of the shift registers, the left most position, and is shifted to position **1** by subseqent data entry. Prior to the start of a scan, the contents of the 28 bit shaft register **750** has been "dumped" and the register was reset to all zeros, but for the first position in which a one was set. When the memory **400** is fully loaded, the data code indicative of a character to be printed in character position one is in storage cell one of the memory shift registers. Once the load cycle is completed and other conditions are present, power is controlled, hammers are cocked, and the like, the first scan begins with subscan **1**. The next character mark sensed by sensor **800** is gated to clock circuit **1010** and trains of clock pulses are generated by the clock **1010**.

In response to the clock pulses the data memory is shifted four positions and the data clock indicative of the desired character to be printed in character position **5** appears at the comparator **500**. Simultaneously, the decrement-by-four circuit **650** causes the character code counter to decrement by four, indicative of the type character **302**, FIG. **3**, on band **300** about to be in registration with character position five **352**. If a favorable comparison results, a match signal is stored in position one of the shift register, shifting the **1** previously stored therein to position two. If an unfavorable comparison occurs, a zero is stored in shift register position **1** again shifting the **1** therein to position **2**.

The memory is shifted by five clock pulses; the data code to be printed in character position **10** is gated to the comparator **500** and the character counter **610** is decremented by a count of four. This character code is also gated to the comparator **500**. Again, if a match occurs, a one is loaded into position one of the shift register **750**, shifting the previously stored levels each one position. This shifting of the memory **400** content, and stepping of the character code counter **610** continues until the 27th comparison has been made. When the result of this comparison is loaded into the 28 bit shift register **750** and the original "one" set therein prior to the commencement of this subscan arrives in cell **28** of the register an "initiate fire pulse" signal is transmitted to the fire pulse generator **730**. Twenty-seven comparisons take approximately 200 microseconds, FIG. **1**.

The five-bit ring circuit **710** previously set to its first position enables the first AND gate **721** to pass the fire pulse from generator **730** to high current amplifier **201**. This completes a circuit consisting of high current amplifier **201**, those of coils **5 10, 15, 20** . . . **130** and low current amplifiers **1** to **27** connected to shift register **750** storage cells having a "one" level indicative of a match stored therein. The fire pulses travel through the designated coils and associated diodes, release the respective hammers and cause the hammers to force the paper against the character band at those positions where a character is to be printed. The first pulse is approximately 600 microseconds in duration, FIG. **1**. The trailing edge of the fire pulse activates trailing edge sensor **740** which emits a pulse, resetting the 28-bit shift register to the predetermined code, a one in position **1** and zeros in positions **2** to **28**. The trailing edge pulse also steps the five-bit ring counter to a count of two, subscan **2**.

During the firing pulse period, the character counter **610** executes six decrement-by-four operations and upon sensing of the next character mark executes an increment-by-one operation, advancing the counter by a count one greater than that contained therein at the start of subscan **1**.

Thus the code generator contains the character code for the type character appearing on the belt subscan **2**, FIG. **3b**, in registration with the next position. The total time for a subscan and a firing subcycle is about 800 microseconds; FIG. **1**, 200 microseconds for the subscan and 600 microseconds of firing time. 800 microseconds is precisely the time it takes the band to move 0.025 inches, the distance that type characters are displaced from character positions.

The character which had been slightly displaced from character position four, FIG. **3b**, is now in alignment with character position four. Similarly, type characters are aligned with positions **9, 14** . . . **129**.

Subscans **2** through **5** occur in the same manner, with the following exception. At the end of subscan **5**, an extra decrement-by-four operation is performed and the character counter now contains the code for the next character to appear in registration with position **5**, FIG. 3b. Thus scan number two is commenced.

It is of particular interest to note, FIG. **1**, that each fire pulse is 600 microseconds in duration, yet hammer flight time is approximately 3,000 microseconds. Thus, after a subscan, the 600 microsecond fire pulse interval occurs, the next three 200 microsecond subscans are accomplished and the third firing pulse is almost completed before the hammers fired in subcycle **1** come to rest. It is seen that the drivers are time-shared, switching from one hammerin a set to other hammers in a set during the flight of the initial 27 hammers.

Scans two to sixty-four proceed in the same manner.

The decimal equivalents of the character codes as they appear in character counter **610**, FIG. **5**, are shown in FIG. 6a. The top most column depicts the comparisons, columns **1** to **27**, made during the subscan and dummy shifts executed by the counter during the firing pulse period following a subscan. The dummy shifts are executed so that the counter may be set to the proper character code when the next successive subscan begins.

FIG. **6b** depicts the meaning of the numbers within a block of FIG. **6a**. The number to the left of the slash indicates the character position at which a character will appear. And the number to the right is the decimal equivalent of the binary character code assigned to that particular character.

Codes are assigned from **00** to **64** in sequence with characters on the band. The code following **64** is **00**.

Assume that during the first subscan the band **300** is positioned such that the character "space" is in registration with character position **5**. During this subscan, character codes and data codes for position **5, 10, 15** . . . **125** and **130** are compared. Thus during the first comparison of this subscan, the code for a space, **00**, is compared to the data code in memory for position **5**. The character appearing in registration with position **10** with be spaced four characters on the band **300**, FIG. **3b**, from the space and is represented by a code having a decimal equivalent four numbers less than **00**, which code is **60**. Similarly the character code representing the type character in registration with position **15** will be four characters distant from the preceding type character which was compared, and will be represented by the character code **56**. Thus each successive character code of the 27 presented during any one subscan is four less than the immediately preceeding code. During subscan **2**, the character on the belt adjacent to the space will be in registration with character position **4**. This character is an "!" and is represented by the character code **01**. Hence during the firing pulse period between subscans **1** and **2**, the counter **610** must be shifted so that at the start of subscan **2** the appropriate character code will be set therein.

At the 27th comparison of subscan **1** the code **24** is set into the counter. The counter must be decremented by a count of **23** so that the counter **610** contains the count **01** at the start of subscan **2**. This is accomplished by decrementing the counter six times by a count of four, a count of **24**, and incrementing by a count of one, for a total change in count of −**23**. The process for changing the count during the firing period is referred to as a dummy shift.

Following subscan **5**, a new scan is started. Since a type character **302** on band **300**, FIG. **3b**, has moved one complete character position, the type character now in registration with position five is represented by a character code value one more than the value of the character in registration at the start of scan **1**. Therefore, the character code **28** contained in counter **610** must be decremented by **27** to arrive at the correct count following subscan **5**. This is accomplished by executing a decrement-by-four six times, performing an additional decrement-by-four, and then incrementing-by-one.

The count contained in counter **610** for a portion of the 64th scan is also shown in FIG. **6a**.

As the counter **610** is changing character codes, memory **400** shift registers will be presenting data codes indicative of the data to be printed in various character positions, such that the data codes and character codes arrive at comparator **500**, FIG. **5**, in timed sequence.

The data code in position one of the memory **400** shift register is shown in the rightmost columns of FIG. **7**. Clock pulse from clock **1010**, FIG. **5**, shift the content of the registers from position to position. Each fifth data code is gated to comparator **500** which comparator is enabled by the frequency divider pulse **1050**, a divide-by-five pulse.

The character position of data codes which are gated to the comparator **500** for each subscan are shown in FIG. 7. At the end of the subscan **1**, data initially stored in position **135** appears at the comparator. It is desired at the start of subscan **2**, that the data code representative of data to be printed in position **2** appear at the comparator. The memory capacity is 150 positions. Hence 15 dummy shifts of data must be executed before The comparison is made. Fifteen dummy shifts are executed and the data in register position **150** is shifted to position one. Scan **2** starts with four clock pulses to memory **400** and data originally in position **4** is shifted to position **1** and gated to comparator **500**.

At the end of subscan **5**, the data for character position **131** is in position **1** of the shift registers **400**. To recycle to subscan **1** again, the data for character position **1** must appear in register position **1**. Twenty dummy shifts must be executed. Twenty clock pulses are transmitted to memory **400**.

FIGS. **8** to **10** depict the clock and timing circuitry in detail. The circuits are interdependent and interconnected with one another.

The clock **1010**, FIG. **8**, includes a pair of monostable multivibrators **1011** and **1012** connected with the reset leads **1017** and **1018** of one to the set terminal of the other. Both circuits are connected to associated AND gates **1013** and **1014**, respectively. The "high" outputs of each clock produce output pulse trains of a duration of 720 and 580 nanoseconds, respectively, which are fed to trailing edge pulse generators, **1015** and **1016**, producing the clock pulses designated as the early and late clock pulses. The "low" terminal outputs, **1017** and **1018**, of each of the multivibrators **1011** and **1012**, are connected through the AND gates **1014** and **1013**, respectively, to the reset terminal of the other of the multivibrators **1012** and **1011**.

An OR gate **1023** is fed by an AND gate **1022**. The output of AND gate **1021** feeds OR gate **1023** and also feeds the set terminal of a print flip-flop **1024**. The output of OR gate **1023** feeds a start clock flip-flop **1025** set terminal.

The reset terminal of flip-flop **1025** is fed by an OR gate **1026**, which in turn is fed by AND circuits **1027** and **1028**.

The start of a print phase is signaled by all inputs to gate 1021 being high; the load phase is not occurring, $\overline{\text{LOAD}}$, and the READY signal indicates that power is up, bailing and paper feed is not being performed and other functions not germane to the invention are or are not occurring. Upon receipt of the next character mark by sensor **800**, print flip-flop **1024** is set by the output from gate **1021**. This output is also fed to set start clock flip-flop **1025** via OR gate **1023** and a start clock signal is fed therefrom to AND gate **1013** which starts the clock, producing waveforms OS1 and OS2, FIG. **11**. Early and late clock pulses are generated by circuits **1015** and **1016**, respectively. Thus, it is seen that all other conditions being proper, at the start of a print cycle the next clock mark from band **300** starts the clock. Since this other AND gate **1022** has an input $\overline{\text{SUBSCAN 1}}$, the trailing edge of the READY pulse will set clock flip-flop **1025** for subscans two to five. Hence at the start of each scan, the clock is resynchronized by the character mark pulses for sensor **800**.

The clock is reset by the combination of AND gates **1027** and **1028** and OR gate **1026**. The clock is not stopped at the end of a subscan, but is stopped after the necessary dummy shifts have been accomplished in character generator **600** and memory **400**. AND gate **1027** stops the clock after subscans one to four and AND gate **1028** stops the clock after subscan five. The output of AND gate **1028** serves as a set input to the first input of the scan counter, FIG. **11**.

Late clock input pulses from the circuit **1016** feed the frequency divider **1030**, FIG. **9**. The circuit consists of flip-flop stages **1031**, **1032**, and **1033** in cascade having high level outputs designated EC1, EC2, and EC3, respectively. Flip-flop **1031** is fed by AND gate **1034**.

The circuit **1030**, counts the late clock pulses and upon receipt of every fifth late clock pulse produces an output pulse.

The end shift counter **1040**, FIG. **10**, is a two-stage counter having flip-flops **1041** and **1042** connected in cascade. Flip-flop **1041** is connected to AND gate **1043** which in turn is connected to input lines designated by EC3 pulse, divide-by-five, and hammer firing pulses. Outputs ESC1 and ESC2 are generated during the firing cycle after each fifth and tenth late clock pulse.

The scan counter **1050**, FIG. **11**, is a six-bit counter having six cascaded flip-flops **1051** to **1056**, which counter produces an output signal after receipt of **64** input pulses from AND gate **1028** of the clock **1010**, FIG. **8**. Thus, at the end of each fifth subscan the counter **610** is stepped by one count. At the end of the 64th scan, the output of the circuit **1050** is fed to the reset terminal of the print flip-flop **1024**, FIG. **8**, to indicate that the print cycle is over.

FIG. **12** shows a character mark pulse which is sensed by sensor **800** and delivered to AND gate **1021**, FIG. **8**. Assuming the $\overline{\text{LOAD}}$ and READY signals are high upon receipt of this pulse, the print flip-flop **1024** is set. The $\overline{\text{PRINT}}$ signal is fed via OR gate **1023** to set the start clock flip-flop **1025** and a START CLOCK level is delivered to AND gate **1013** along with a pulse from monostable multivibrator **1012** via lead **1018** to start monostable multivibrator **1011**, producing the first OS1 pulse. This pulse fed to trailing edge detector also produces the first of the early clock pulses. The multivibrator remains on for 720 nanoseconds and then switches to its other state causing lead **1017** to be high, feeding a signal via gate **1014** to switch multivibrator **1012** on for the duration of 580 nanoseconds, OS2. The OS2 pulse is fed to trailing edge detector **1016** which produces late clock pulses. At the end of 580 nanoseconds, the low terminal of multivibrator **1012** feeds a signal to AND gate **1013** which in combination with the START CLOCK signal from flip-flop **1025** triggers circuit **1011** to initiate another clock cycle.

The pulse EC 3, FIG. **12**, is generated by the frequency divider of FIG. **9**. Both clock pulses from detector **1016** are fed to this counter circuit. Upon the receipt of the fourth such pulse, flip-flop **1033** is high and until the next late clock pulse resets the flip-flop, the signal remains on whereupon a divide-by-five pulse is initiated.

The character counter **610**, FIG. **13**, is a six-bit counter consisting of cascaded flip-flop **611** to **616**. The preset circuit **620** consists of AND gate 620 having an input from fiduciary sensor **900** and a $\overline{\text{PRINT}}$ input from the print flip-flop **1024**, FIG. **8**. Outputs from this gate **620** set counter stages **611** and **616** producing the preset character code for type character "A", **10001**.

The increment-by-one circuit **630** consists of an OR gate **631** connected to the least significant bit position of counter **610**, flip-flop **611**, and further consists of two AND gates **632** and **633**, which provide inputs to OR gate **631**.

The decrement-by-four circuit **650** consists of an OR gate **651** connected to flip-flop **613** of the counter **610**. OR gate **651** is fed by AND gates **652**, **653**, **654**.

The output of AND gate **632** steps the counter by one upon the receipt of character marks from sensor **800** during the non-print cycles to keep the character generator count updated as described hereinbefore.

EC3, FIG. **14** and **15**, pulses are generated, FIG. **9**, between each fourth and fifth late clock pulse and EC2 pulses are generated between each second and fourth late clock pulse. ESC1 and ESC2 pulses from endshift counter **1040**, flip-flops **1041** and **1042** are generated following the receipt of the first and second EC1 pulses, respectively during the occurrence of a fire pulse.

FIG. **14** depicts the timing necessary to execute decrement-by-four shifts during the subscans and dummy shifts in the character counter **610** after subscans one to four: six decrement-by-four shifts and one increment-by-one shift; FIG. **15** depicts the timing necessary to execute dummy shifts in the character counter **610** after subscan five.

Referring now to FIGS. **13** and **14**, AND gate **652** is high producing a decrement-by-four signal from circuit **650** upon the occurrence of a divide-by-five waveform, FIG.**12**, a late clock pulse and a ready signal. Recalling the memory **400** is shifted by five positions for each comparison and the character counter is shifted by four counts for each comparison.

Dummy shifts in the code counter **610**, subscans one to four, are executed only when hammers are firing, following each subscan, and upon the receipt of a $\overline{\text{ESC2}}$, FIG. **10**. From FIG. **14** it is seen that six decrement-by-four pulses are gated to OR gate **651** from AND gate **653** before the $\overline{\text{ESC2}}$ pulse is high.

The increment-by-one pulse executed during a dummy shift is generated by gate **633** after the clock has been stopped by AND gate **1027**, and upon receipt of the last early clock pulse.

Fifteen early clock pulses corresponding to 15 pulses from clock clip-flop **1011** are gated to memory prior to stopping of the clock, FIG. **6**.

Referring to FIG. **15**, six decrement-by-four pulses are gated to character code counter **610** by AND gate **653** and OR gate **651**, as described supra. During the fifth subscan, however, an additional decrement-by-four pulse is passed by AND gate **654** upon the occurrence of the 20th early clock after the subscan or when an early clock pulse arrives in coincidence with an output from both stages of the end shift counter, ESC1 and ESC2, and an output from the stage of divide-by-five flip-flop **1032**.

Thereafter, AND gate **633**, passes an increment-by-one pulse to character counter **610** to complete the dummy shifts of the counter during subscan five. Twenty early clock pulses have been received by memory to shift memory input by twenty cells at the end of subscan five, see FIG. **6**.

Since 15 or 20 dummy shifts of memory **400** must be made prior to commencement of a subscan, the clock must continue for 15 or 20 pulses OS1 from clock flip-flop **1011**.

From an examination of FIG. **13**, it is evident that following scans one to four, the coincidence of pulses ESC2 and EC2 occurs only during the receipt of the 15th late clock pulse, hence AND gate **1027** will only reset the flip-flop **1025** after the necessary clock pulses have been received.

Similarly, following subscans **5**, FIG. **14**, the simultaneous occurrence of a late clock pulse, and outputs ESC1, ESC2, and EC2, FIGS. **8** and **9** occurs only during the 20th late clock pulse to gate AND gate **1028**.

It is seen that the increment by one AND gate **633** will only pass the last early clock pulse via enabled AND gates **1027** and **1028**, FIG. **7**.

Other embodiments will occur to those skilled in the art and are within the following claims:

What is claimed is:

1. An impact printer comprising a continuously moving type carrier with a number of characters thereon defining at least one type font, a plurality of sets of impacting hammers, *each hammer having a position within one of said sets, the hammers in like positions among the sets being simultaneously in alignment with respective ones of said characters*, said hammers being adapted to be moved from a cocked position to an impact position, the total number of hammers equal to the number of character positions defining a line of print, each line of print being applied sequentially, holding means for maintaining each of said hammers in said cocked position, releasing means coupled to each of said holding means and responsive to activation thereof for selectively releasing each hammer to said impact position to coact withsaid carrier and thereby impacting a print medium, each hammer having a predetermined flight time from said cocked position to said impact position, a plurality of *time-shared hammer* drivers *in one to one correspondence with said hammer sets* coupled to said releasing means for selective activation thereof by application thereto of a release pulse said release pulse being of substantially less duration than said hammer flight time, means for coupling each said driver to various ones of said releasing means during each said line print sequence **[**for supplying**]** *and adapted to supply*a plurality of sequential release pulses from **[**at least one**]** *each* driver to a plurality of releasing means *respectively associated with the hammers of the set corresponding to said driver*, during a single hammer flight time, *release pulses being simultaneously applied to release means associated with hammers occupying like positions in different sets*, a first sensing means responsive to said character type and coupled to a character code generator, a memory containing sequences of desired character information, a comparator, said comparator responsive to said memory and said character code generator and coupled to said drivers for selectively actuating said drivers to release hammers in accordance with said sequences of desired character information, a plurality of fiduciary marks on said type carrier, second sensing means responsive thereto, a timing means responsive to said second sensing means for providing timing pulses, and means coupling said timing pulses to said comparator and said driver for synchronizing operation thereof in accordance with character position relative to hammer locations.

2. The printer of claim **1** further comprising:

magnetic means for restraining said hammers against movement when in said cocked position.

3. The printer of claim **2** wherein said magnetic means is a permanent magnet.

4. The printer of claim **3** wherein said release means comprise electrical coils wound about said magnets.

5. The printer of claim **4** wherein said release means further comprises:

means to pass a current through said coils to create a magnetic force in opposition to the magnetic force of said magnets.

6. The printer of claim **1** wherein the spacing between type characters on said carrier is different from the spacing between character positions on said line.

7. The printer of claim **6** wherein the spacing between type characters is greater than the spacing between character positions.

8. The combination of claim **1**, wherein said character code generator comprises a character counter having an output coupled to said comparator, a preset means responsive to said second sensing means for resetting said character code counter, a variable delay means responsive to said first sense means and coupled to said character code counter by an increment by one device, and a decremental device coupling said second means to said character code counter, said decremental device reducing the input character count to said character code counter by the frequency at which hammers and characters are in registration.

9. The combination of claim **1**, wherein said character code generator responds to said second sensing means and is set in response to a fiduciary mark, and responds to said first sensing means by stepping a count of one for each sensed character mark, whereby said character generator is kept current with movement of said carrier.

10. An impact line printer comprising a continuously moving type carrier with a number of characters thereon defining at least one type font, a plurality of sets of impacting hammers, *each hammer having a position within one of said sets, the hammers in like positions among the sets being simultaneously in alignment with respective ones of said characters,* said hammers being adapted to be moved from a cocked position to an impact position, each line of print being applied sequentially, said hammer centers being positioned closer together than said type characters, said hammers operative by release of stored kinetic energy retained by said cocked hammers, holding means for maintaining each of said hammers in said cocked position, releasing means coupled to each of said holding means and responsive to activation thereof for selectively releasing each hammer to said impact position to coact with said carrier and thereby impacting a print medium, each hammer having a predetermined flight time from said cocked position to said impact position, a plurality of *time-shared* drivers *in one to one correspondence with said hammer sets* coupled to said releasing means for selective activation thereof by application thereto of a release pulse, said release pulse being of substantially less duration than said hammer flight time, means for coupling each said driver to various ones of said releasing means during each line print sequence [for supplying] *and adapted to* a plurality of sequential release pulses from [at least one] *each* driver to a plurality of releasing means *respectively associated with the hammers of the set corresponding to said driver,* during a single hammer flight time, *release pulses being simultaneously applied to release means associated with hammers occupying like positions in different sets,* a first sensing means responsive to said character type and coupled to a character code generator, a memory containing sequences of desired character information, a comparator, said comparator responsive to said memory and said character code generator and coupled to said drivers for selectively actuating said drivers to release hammers in accordance with said sequences of desired character information, a plurality of fiduciary marks on said type carrier, second sensing means responsive thereto, a timing means responsive to said second sensing means for providing timing pulses, and means coupling said timing pulses to said comparator and said driver for synchronizing operation thereof in accordance with the position of a character relative to a hammer location.

11. An impact line printer comprising a continuously moving type carrier with a number of characters thereon defining at least one type font, a plurality of sets of impacting hammers, *each hammer having a position within one of said sets, the hammers in like positions among the sets being simultaneously in alignment with respective ones of said characters,* said hammers being adapted to be moved from a cocked position to an impact position, holding means for maintaining each of said hammers in said cocked position, releasing means coupled to each of said holding means and responsive to activation thereof for selectively releasing each hammer to said impact position to coact with said carrier and thereby impacting a print medium, each hammer having a predetermined flight time period from said cocked position to said impact position, a plurality of *time-shared* drivers *in one to one correspondence with said hammer sets* coupled to said releasing means for selective activation thereof by application thereto of a release pulse, said release pulse being of substantially less duration than said hammer flight time period, means for coupling each said driver to various ones of said releasing means during each line print sequence [for supplying] *and adapted to supply*a plurality of sequential release pulses from [at least one] *each* driver to a plurality of releasing means *respectively associated with the hammers of the set corresponding to said driver,* during a single hammer flight time period, *release pulses being simultaneously applied to release means associated with hammers occupying like positions in different sets,* a first sensing means responsive to said character type and coupled to said drivers for selectively actuating said drivers to release hammers in accordance with desired character information, a source of sequential timing signals, second sensing means responsive to said timing signals, a timing means responsive to said second sensing means for providing timing pulses derived from said timing signals, and means coupling said timing pulses to said drivers for synchronizing operation thereof in accordance with the position of a character relative to a hammer location.

12. The combination of claim **11**, wherein each said release pulse duration is less than one quarter of the average hammer flight time.

13. The printer of claim **11** further comprising: magnetic means for restraining said hammers against movement when in said cocked position.

14. The printer of claim **13** wherein said magnetic means is a permanent magnet.

15. The printer of claim **14** wherein said release means comprise electrical coils wound about said magnets.

16. The printer of claim **15** wherein said release means further comprises:

means to pass a current through said coils to create a magnetic force in opposition to the magnetic force of said magnets.

17. The printer of claim **11** wherein the spacing between type characters on said carrier is different from the spacing between character positions on said line.

18. The printer of claim **17** wherein the spacing between type characters is greater than the spacing between character positions.

19. A printer according to any of claims 1, 10, or 11, where the hammers in each set are adjacent one another.

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