

## [54] HAMMER BANK MOVE CONTROL SYSTEM

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[51] Int. Cl.<sup>2</sup> .... **B41J 9/12**

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 101/93.13, 93.14, 93.15, 93.16-93.18, 110,  
 93.28, 93.29; 197/1 R, 49, 18; 340/172.5

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Primary Examiner—J. Reed Fisher

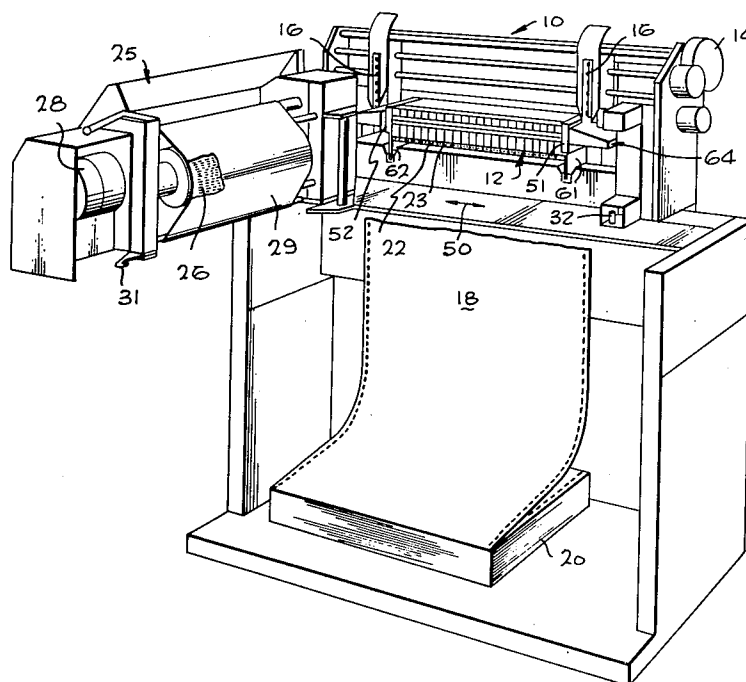
Assistant Examiner—R. T. Rader

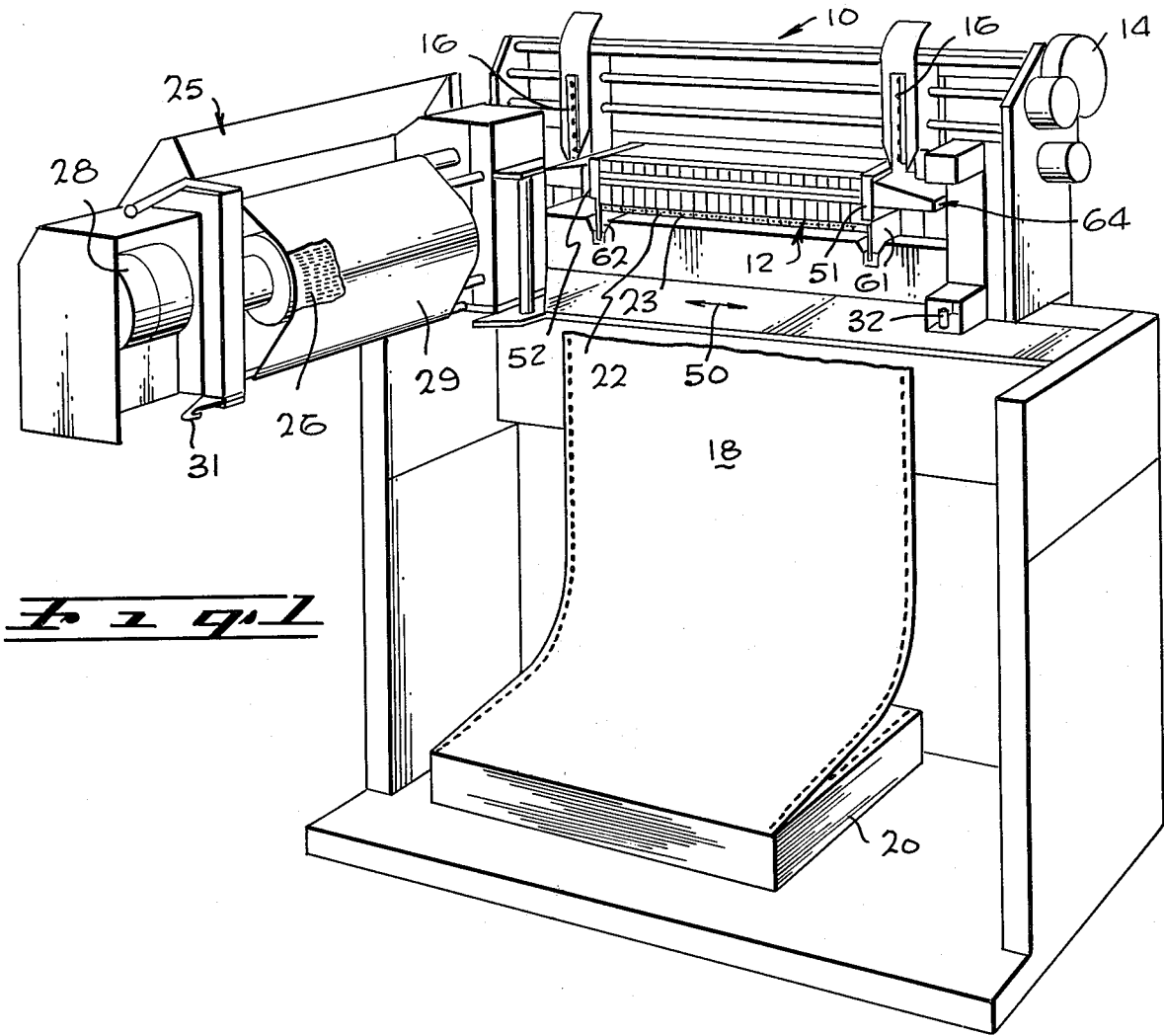
Attorney, Agent, or Firm—Lindenberg, Freilich,  
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## [57] ABSTRACT

A hammer bank system for use in a high speed impact printer includes a movable hammer bank in which the hammer spacing is twice the character spacing. A hammer bank controller is used to move the entire hammer bank between two selected hammer bank positions. In one hammer bank position, the hammers are aligned with odd character positions and in the other hammer bank position, the hammers are aligned with the even character positions. The hammer bank controller in response to a move command signal from the printer logic section drives the hammer bank (in a velocity mode) from one of its positions to the other first at an increasing velocity, followed by a constant velocity, until the bank is at a selected distance from the desired position, at which time the hammer bank velocity is decreased to zero and the hammer bank is substantially at the desired position. The controller switches to a position mode in which a position signal is used in a position servo loop to lock the hammer bank at the desired position. In normal operation when the bank is switched to the position mode, a move complete signal is fed back to the printer logic section to terminate the move command signal. Positioning initialization circuitry is also included to automatically drive the hammer bank to one of its desired positions.

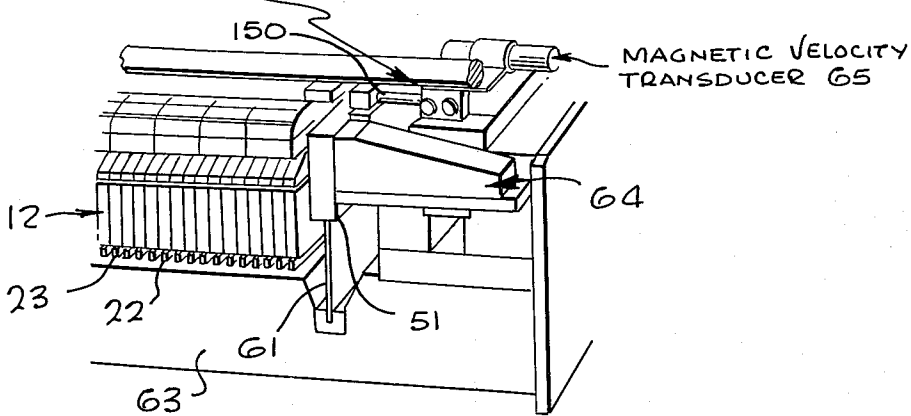
17 Claims, 8 Drawing Figures

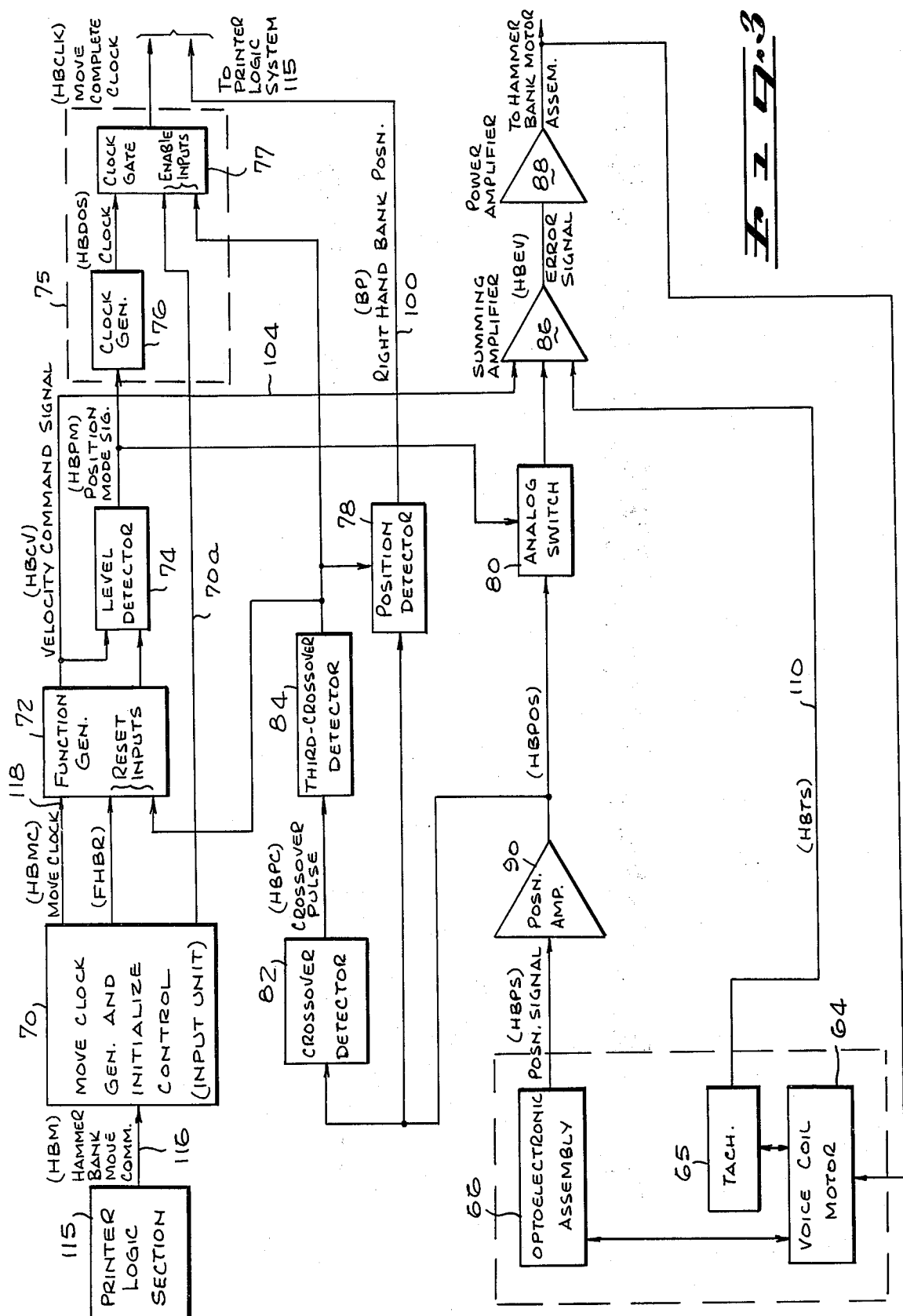




OPTICAL POSITIONER  
TRANSDUCER 66

**Fig. 2**





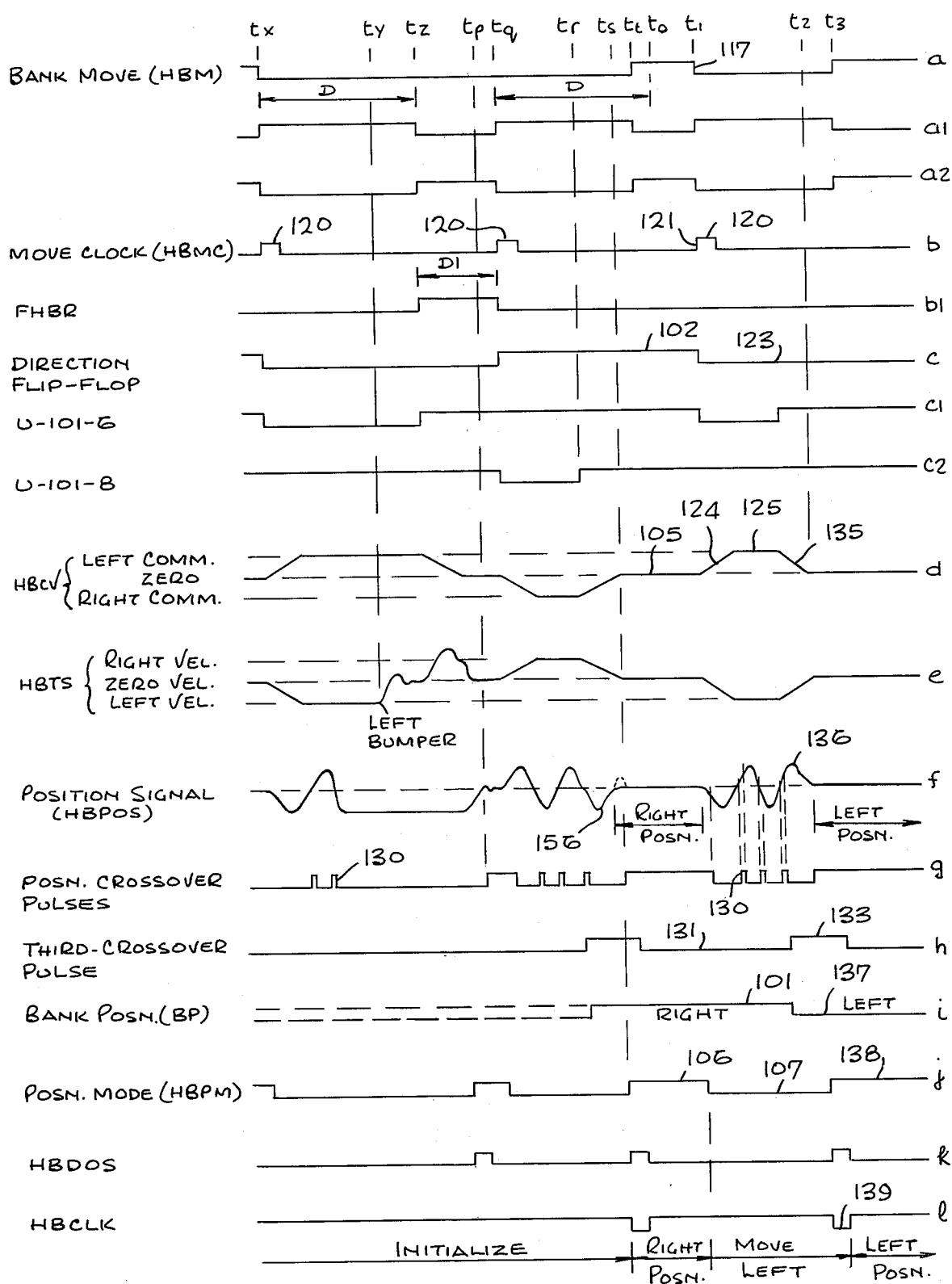
Fig. 4

Fig. 5

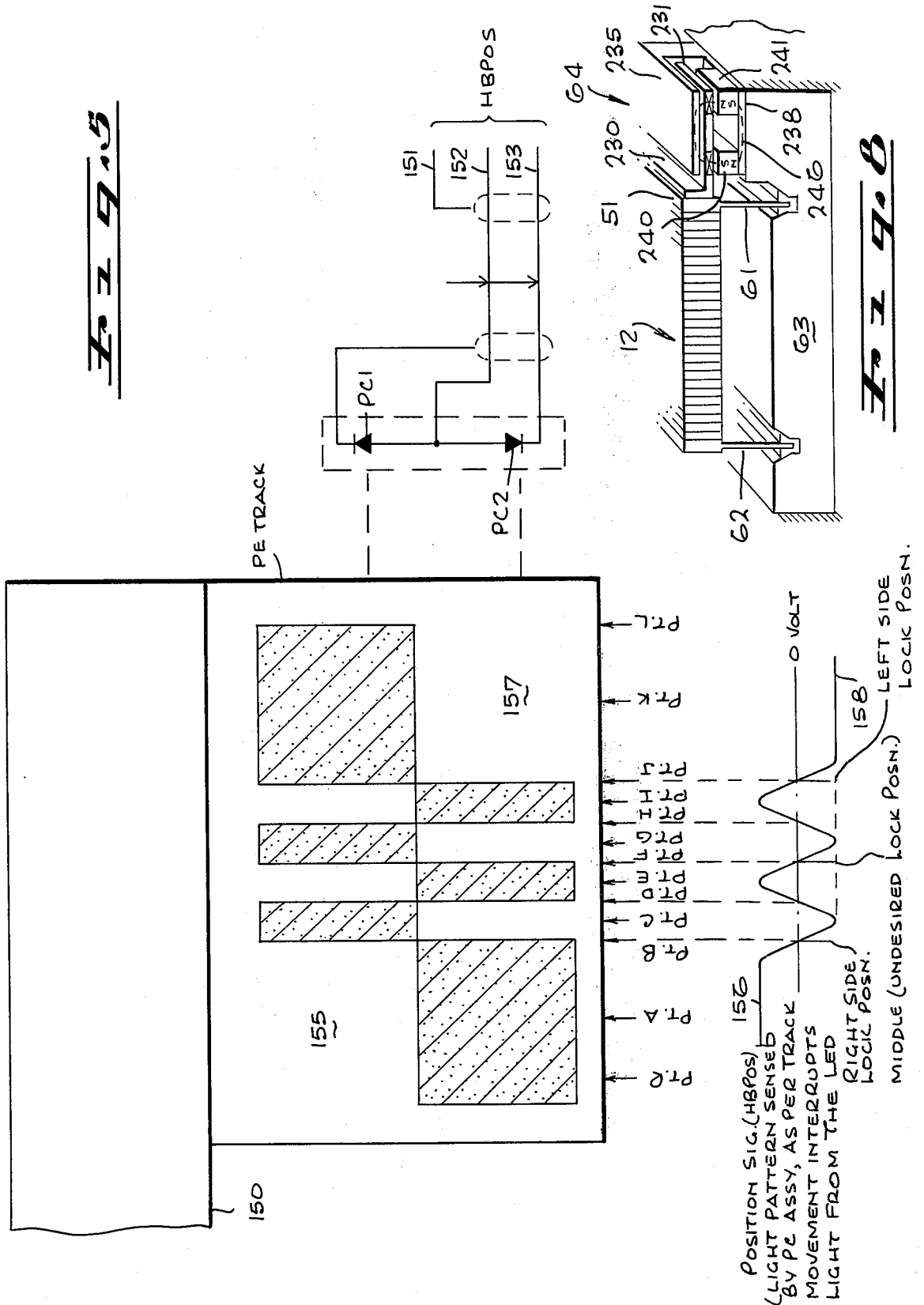
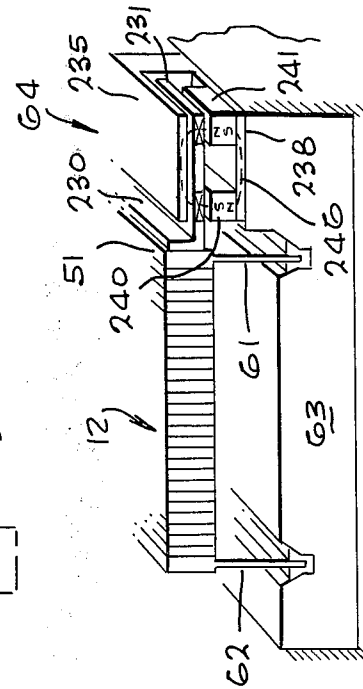
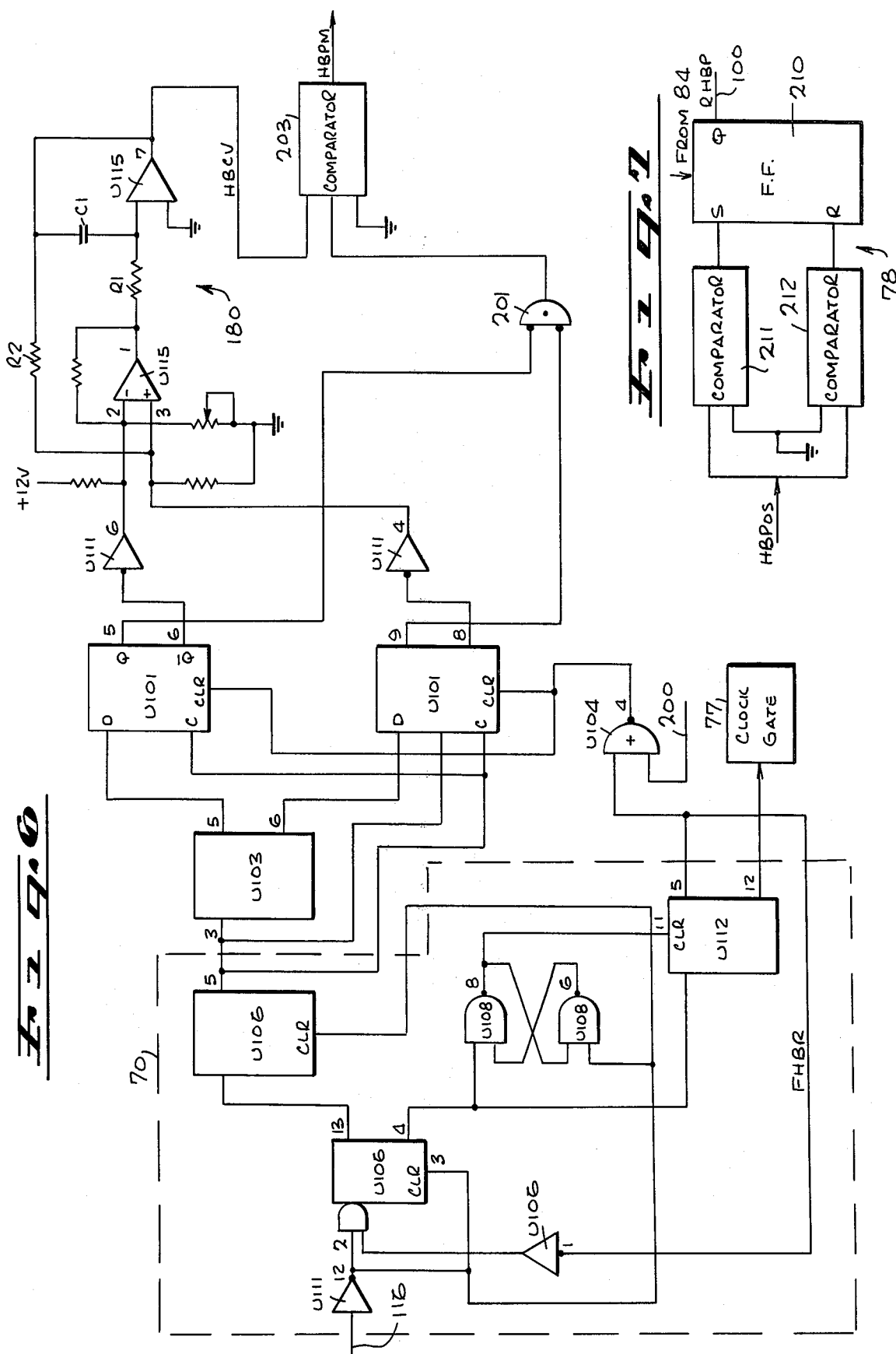


Fig. 6





## HAMMER BANK MOVE CONTROL SYSTEM

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention generally relates to impact printers and, more particularly, to a hammer bank controller for controllably moving and positioning a bank of print hammers in an impact printer.

## 2. Description of the Prior Art:

Impact printers are well known in the data processing field for providing hard copy computer output. Typically, such printers comprise a type surface, such as character drum or chain, which continually moves past a printing station, comprised of a bank of aligned individually actuatable hammers. A paper web and an ink web are disposed between the hammer bank and the type surfaces. Printing is accomplished by actuating each hammer at the appropriate time to propel it against the type surfaces when the character to be printed moves into alignment with the hammer striking face.

Typically, the number of hammers in the bank is equal to the number of characters printable on each line. The spacing between the centers of adjacent hammers, referred to as hammer spacing is equal to the desired spacing between the centers of adjacent characters or the character spacing. For example, if the character spacing is 0.100 inch, the hammer spacing is 0.001 in. In a printer with a capability of printing 136 characters per line, 136 hammers are required. Each hammer is used for printing a character at a different-print position along the print line. The print positions can be thought of as a sequence of odd and even positions, with the odd hammers in the bank being aligned with odd positions and the even hammers being aligned with the even positions.

The cost of fabricating and maintaining a bank with a large number of hammers which are closely and accurately spaced is quite high, thereby increasing the overall cost of the impact printer.

## SUMMARY OF THE INVENTION

In view of the foregoing an object of the present invention is to provide an impact printer with a reduced number of hammers without reducing the number of print stations, i.e., the number of characters printable per line.

Another object of the invention is to provide a printer with a hammer bank and a hammer bank controller whereby each hammer is accurately positionable at either of two print positions thereby serving at more than one print position, resulting in halving the number of hammers in the bank.

A further object of the invention is to provide a hammer bank controller for moving a hammer bank between two positions and for accurately positioning the bank at either position each hammer is aligned with an even print position.

These and other objects of the invention are achieved by providing in one embodiment of an impact printer a hammer bank in which the hammer spacing i.e., the spacing between adjacent hammers' centers is twice the spacing between adjacent print station centers or the print station spacing which represents the character spacing. The bank is movable under the control of a multimode hammer bank controller between two precise positions spaced apart a distance equal to the print

station spacing. In one bank position the hammers are aligned with selected print stations, e.g., the odd stations. In the other bank position, the hammers are aligned with the other stations, e.g., the even stations. Thus, each hammer is successively alignable with an odd and an even print station. The controller, responsive to a command signal includes means for moving the bank in a velocity mode from one bank position to the other bank position, at a controlled velocity profile. As the bank position to which the bank is moved is approached, the bank velocity is reduced until it reaches the desired position. Thereat the controller switches to a position mode in which the bank is controlled to be precisely positioned and maintained at the desired station. A subsequently received command signal activates the controller to return the bank to the other position in the velocity mode and thereafter hold it thereat in the position mode.

In an embodiment to be described hereinafter means are included for initializing the system to initially drive the bank to one of the two bank positions and thereafter move it between the two positions in response to each received command signal. In this embodiment means are provided in the controller to sense, automatically, the bank positions at which the bank is positioned and to provide an indication thereof to the printer logic section which controls all the printer's operations.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of an impact printer of the type in which the present invention is incorporated;

FIG. 2 is a partial view of the hammer bank and some of the circuits forming part of the hammer bank controller;

FIG. 3 is a block diagram of the novel hammer bank controller;

FIG. 4 is a multiline waveform diagram useful in explaining the operation of the novel hammer bank controller;

FIG. 5 is a diagram of a novel position transducer used in the present invention;

FIGS. 6 and 7 are combination block and schematic diagrams of circuits shown in FIG. 3; and

FIG. 8 is a cross section diagram of a voice-coil type motor used in the novel controller.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Attention is now called to FIG. 1 which illustrates a high speed impact printer exemplary of the type generally employed for data processing application. Briefly, the printer of FIG. 1 is comprised of a first frame 10 supporting a hammer bank 12 and a paper stepping system, generally comprised of motor 14 driving tractor chains 16. The chains 16 pull edge perforated paper 18 from a supply stack 20 past the hammer faces 22 of hammers 23 of the hammer bank 12. The printer of FIG. 1 also includes a second frame 25 which is hinged with respect to the frame 10. The frame 25 supports a movable type bearing surface such as a horizontally oriented multitrack drum 26 which is rotated about is axis by a motor 28. Means are provided for passing a printing ribbon 29 between the rotating character drum 26 and the hammer faces 22.

In the operation of the printer of FIG. 1, the edge perforations of the paper 18 are engaged with the

sprockets of the chains 16 to thus enable the motor 14 to pull the paper past the hammer faces 22. Normally, the motor 14 steps the paper one line at a time. Printing, of course, can be accomplished only when the frame 25 is pivoted to a closed position relative to the frame 10 and locked thereto, as by cooperating latch portions 31 and 32. In this closed operative position, the hammer faces 22 will be disposed very close to the paper which in turn will be disposed very close to the printing ribbon 29.

As the character drum 26 rotates, it cyclically passes different raised characters in front of each hammer face. By actuating a hammer at an appropriate time, the hammer face is propelled against the backside of the paper, forcing the paper against the ribbon 29 and drum 25 to thus print a character on the front side of the paper.

Each character along the line is printable at a different print station. Typically, in prior art printers, the number of hammers in the hammer bank 12 is equal to the number of print stations, one hammer per print station. For example, for 136 characters per line, i.e., in a printer with 136 print stations with a character (station) spacing of 0.100 in. a bank of 136 hammers with a hammer spacing of 0.100 inch is required.

The present invention is directed to a printer with a hammer bank with fewer hammers than the number of print stations and with a bank controller for moving the bank precisely between different positions, so that each hammer is alignable successively to serve at more than one print station.

In accordance with the present invention the hammer bank rather than being rigidly supported in structure 10 is movable therein along the print line direction represented in FIG. 1 by numeral 50. To facilitate bank movement the end plates 51 and 52 of hammer bank 12 are shown in FIGs. 1 and 2 respectively, supported by flex pivots 61 and 62, on structure 63 which forms part of frame 10. FIG. 2 is a partial view of the bank and some of the parts included in bank controller in accordance with the invention. The bank is moved by a voice coil motor 64. The bank velocity is sensed by a magnetic velocity transducer e.g., tachometer 65, which as will be explained hereinafter, provides a dc output whose amplitude is related to the bank velocity and whose polarity is related to movement direction. An optical positioner transducer 66, hereinafter referred to as the position transducer, is also included. As will be explained hereinafter, the output of the latter is used to maintain the bank at one of its desired positions, once reaching the position, as well as to control the motion of the bank between positions.

The novel hammer bank controller of the present invention in addition to the motor 64, the velocity transducer 65 and the position transducer 66, which together can be regarded as forming a hammer bank motor assembly, also includes circuitry best described in conjunction with FIG. 3, which is a block diagram of circuitry actually reduced to practice. The circuitry, shown in FIG. 3, will be explained in conjunction with a multiwaveform diagram shown in FIG. 4. The circuitry includes a move clock generator and initialize control unit, hereinafter referred to as input unit 70, a function generator 72, a level detector 74, an output unit 75, consisting of a clock generator 76 and a clock gate 77, a position detector 78, an analog switch 80, a crossover detector 82, a third crossover detector 84, a

summing amplifier 86, a power amplifier 88 and a position amplifier 90.

The circuitry may best be described by assuming that the hammer bank 16 is movable between a RIGHT position and a LEFT position and that at a time  $t_0$  (see FIG. 4), the hammer bank is at the RIGHT position. The fact that the bank is at the RIGHT position is indicated by a high bank position (BP) output of position detector 78 on line 100 (FIG. 3) as represented by 101 in line  $i$  FIG. 4. A direction flip flop in generator 72 is shown in a set state, as represented by 102 in line  $c$ . As will be pointed out, this flip flop changes state each time the controller is commanded to move the bank from one position to the other or during initialization. When the bank is at the RIGHT position (or the LEFT) the output signal on line 104 (FIG. 3) from generator 72 to amplifier 86 is zero, as represented by 105 in line  $d$ . This output represents a velocity command signal (HBCV). It is also supplied to level detector 74, whose output represents a position mode signal (HBPM), which is supplied to switch 80. when HBCV is zero, HBPM is high, as indicated by 106 in line  $j$ . When HBPM is high, the controller is in the position mode, and is in the velocity mode when HBPM is low, as represented by 107 in line  $j$ .

When HBPM is high, switch 80 is enabled. It supplies the position signal HBPOS of position amplifier 90 to summing amplifier 86. Amplifier 90 only amplifies the output of the position transducer 66. As will be pointed out hereinafter, when the bank is at either position the output of the transducer 66 is zero. It is positive or negative respectively when the bank deviates to right or left of the desired position. Any deviation is amplified by amplifier 90 and is applied through switch 80 to summing amplifier 86. It sums HBPOS with the tachometer output HBTS on line 110, (as well as HBCV which is zero in the position mode), to provide an error signal HBEV to amplifier 88. The latter drives motor 64 to reduce the bank deviation from the desired position and thereby maintain the bank at the desired position.

The change in the bank position from one position to the next is commanded by the printer logic section 115 (FIG. 3) by providing a hammer bank move command signal HBM\* to input unit 70 on line 116. The printer logic section 115 is a part of the printer which controls all the printer's operations. It is not part of the present invention. The command is represented by a high-to-low transition 117 shown in line  $a$  at time  $t_1$ . Unit 70, upon sensing a low on line 116 provides a move clock pulse (HMBC) on line 118 to function generator 72. One HMBC pulse is represented by 120 in line  $b$ . Its leading edge 121 derives the direction flip flop in generator 72 (see line  $c$ ) from the set state assumed to be present prior to  $t_1$  and represented by 123. When reset, the generator 72 generates the HBVC (line  $d$ ) which ramps up from zero as represented by 124 in line  $d$ , until it reaches a desired level 125. As HBCV increases above zero, the output HBPM of level detector 74 goes low (see line  $j$ ) thereby indicating the end of position mode and the start of the velocity mode. When HBPM goes low switch 80 is disabled. Thus, the position signal HBPOS is not applied to the summing amplifier 86.

The velocity command signal (HBCV) is applied via line 104 to the summing amplifier 86, whose output HBEV feeds the power amplifier 88 which drives the hammer bank via the motor 64. The bank velocity is

sensed by the tachometer 65 which develops a tachometer signal (HBTS) which is of opposite polarity and essentially of equal magnitude compared to the applied velocity command signal. The tachometer signal (HBTS), shown in line *e*, is fed back to the summing amplifier which sums it algebraically together with the velocity command signal HBCV to generate the error signal, HBEV. The error signal therefore is proportional to the difference between the applied velocity command signal and the tachometer signal which is fed back to the summing amplifier. Due to this basic servo feedback action, the error signal HBEV applied to the power amplifier 88 is automatically of the desired strength so that when amplified by the power amplifier 86, it drives the motor 64 with sufficient strength to cause the hammer bank to move at the command velocity level.

As previously pointed out when the bank is at the RIGHT (or LEFT) position, the output of the position transducer 66 and therefore the output of amplifier 90 is zero. The transducer is designed so that as the bank moves from one bank position to the other, its output crosses the zero level three times. The zero of the amplifier 90, which is the position signal HBPOS, corresponding to the position transducer output, is shown in line *f*. As the velocity command signal first ramps up (line 124 in line *d*) after  $t_1$  and then reaches its desired level 125, the bank is first accelerated and then moved at a constant velocity toward the LEFT position. Consequently, the output HBPOS crosses the zero level several times. Each crossing is detected by crossover detector 82 which provides a corresponding crossover pulse, designated in line *g* by 130.

Each of these pulses is counted by the detector 84. The latter is assumed to be initially reset by HBM\* being high during time  $t_0$  (see line *a*) to a low level as represented by 131 in line *h*. Upon counting the third pulse its output goes high as represented by 133. The position transducer 66 is designed so that crossover detector 82 produces the third pulse when the bank is close to the desired position.

The low to high transition of the output of detector 84 (see line *h*) causes several things to take place. Most importantly, it provides a reset control signal to the generator 72. The latter ramps, as represented by 135, from level 125 (see line *d*) to zero, which causes the velocity of the bank to decelerate to zero velocity. Also, the low to high transition of the output of detector 84 activates the position detector 78. The position detector 78 in essence monitors the polarity of the position signal, HBPOS. As will be explained hereinafter when the bank moves to the LEFT position during the deceleration time of the bank, the polarity of HBPOS is positive as designated by 136 in line *f*, and is negative when the bank decelerates towards the RIGHT position. When the position detector 78 is activated and the position signal HBPOS is positive thereby indicating that the bank approaches the LEFT position the detector output BP goes low as indicated by 137 in line *i*. However, if after the third pulse the position signal HBPOS is negative the output BP goes high.

The generator 72 is designed so that after being reset by detector 84 in response to third pulse, it ramps back to zero (135 in line *d*) at a rate so that when its output, i.e., HBCV, reaches zero, the bank is at the desired position, LEFT, in the present example. When the velocity command signal HBCV decreases to zero at  $t_2$ , the

output HBPM of level detector 74 goes high, as represented by 138 in line *j*, thereby indicating the end of the velocity mode and the start of the position mode. In this mode, as previously pointed out, the switch 80 is enabled so that the output of HBPOS of position amplifier 90, together with the tachometer signal HBTS are supplied to the summing amplifier 86 along with the velocity command signal (now zero) to control the error signal and thereby the bank position.

In the position mode, the servo loop responds to the position signal HBPOS, corresponding to the actual bank position at or near the desired position, and the fed back tachometer signal, HBTS. In this mode like in the velocity mode, the velocity command signal HBVC is also supplied to the summing amplifier 86. Since HBCV is zero, basic servo feedback theory indicates that both the HBPOS and HBTS signals also be zero. Any deviation from zero produces an error signal, HBEV, which will cause an appropriate correction in the bank's position so as to reduce the error. This basic feedback correction thereby establishes and thereafter maintains the desired position which is the LEFT position in the present example.

When the HBPM goes high at  $t_2$  (line *j*) it also indicates the completion of the desired bank movement. It activates the clock generator 76 in output unit 75 to send a move complete clock pulse HBCLK\*, represented by 139 in line *l* to printer logic section 115. Its reception by section 115 indicates that the bank is at one of the two desired positions (LEFT in the present example). The specific position is indicated by the level of the output BP of the position detector 78 which is also supplied to the section 115 via line 100. Briefly, output unit 75 produces the HBCLK\* pulse when HBPM goes high, the output of detector 84 is high indicating the reception of three crossover pulse 130, and a signal on line 70a (see FIG. 3) is high. The latter is high only if the other two signals occur within a fixed time from the start of the move command signal HBM\*.

After receiving the move complete clock HBCLK\* the printer logic section 115 sets its output line 116 to high as indicated in FIG. 4, line *a* at time  $t_3$  thereby acknowledging the bank position. The bank is maintained at the LEFT position by the position servo loop in the position mode until a subsequent bank move command HBM\* is received, which is represented by another low level on line 116. As long as the bank is at the LEFT position, the direction flip flop in generator 72 is in its reset state, as represented by 123 in line *c*. Also, the output BP of the detector 78 is low (see line *i*) to thereby indicate to the printer logic section 115 that the bank is at the LEFT position.

To move the bank from the LEFT to the RIGHT position another HBM\* is supplied by the printer logic section 115 to input unit 70. In response thereto, input unit 70 produces another pulse 120 which switches the state of the direction flip flop in generator 72. Since the latter was in its reset state, it is driven to the set state. As a result, the velocity command signal HBCV, produced by the generator 72, ramps down rather than up, until it reaches a desired negative level with respect to zero. As soon as HBCV deviates from zero, level detector 74 produces a low HBPM which disables switch 80. Thus, the system is switched to the velocity mode. The shape of the generator output HBCV and that of the tachometer output HBTS when the controller is in the ve-

locity mode when moving the bank from left to right are the reverse of their shapes when the bank is moved from right to left, as shown in lines *d* and *e*.

When the third crossover is sensed, the detector 84 resets the function generator 72 to ramp back to zero and thereby decelerate the bank. Also, the detector 84 activates the position detector 78 whose output BP changes from low to high to indicate that the bank is approaching the RIGHT position. When the HBCV reaches zero, HBPM goes high enabling switch 80 and thereby switching the controller from the velocity mode to the position mode to hold the bank at the RIGHT position. When HBPM goes high, the output unit is activated to produce the move complete clock HBCLK\* which is supplied to the printer logic section 115. The latter then returns the level of line 116 to high. Since BP on line 100 is high, it indicates that the bank is at the RIGHT position.

From the foregoing, it should be apparent that once a bank position is reached, the controller holds the bank at the position by means of the position servo loop. The actual position of the bank is known by the printer logic section 115 by the level of the bank position BP output of position detector 78. Position change takes place by providing the controller with the hammer bank move command, HBM\*. Upon receiving the command the controller automatically switches to its velocity mode in which the bank is driven from one position e.g., the RIGHT to the other e.g., LEFT. The motion is controlled by the velocity servo loop in which the output of the power amplifier 88, which drives the motor 64 to drive the hammer bank, is a function of the velocity command signal HBCV from the function generator 74 which is compared (summed) with the feedback tachometer signal HBTS by the summing amplifier 86. In the velocity mode, switch 80 is opened and therefore the position signal is inhibited from reaching the summing amplifier.

Before describing other novel aspects of the invention, attention is directed to FIG. 5, useful in explaining the novel position transducer 66 which drives the position amplifier 90. The transducer 66 includes a position encoder (PE) track which is mounted on a shaft 150 (see FIGS. 2 and 5) which is in turn coupled to the movable hammer bank. Thus, whenever the latter moves the position PE track moves in the same direction. Fixedly positioned on one side of PE track is a light source such as a light emitting diode (LED), which is not shown, and a pair of photocells PC1 and PC2, also referred to as the top PC and bottom PC, respectively. They are fixedly positioned on the other side of the PE track. The track, which has top and bottom halves, defines a light and dark pattern. The dark pattern areas are represented by the cross hatched areas in FIG. 5. Light from the light source reaches the top PC (or bottom PC) only when a light pattern area of the top (or bottom) half of the track is between it and the light source, while a dark area of the top (or bottom) half blocks off any light from the top (or bottom) PC.

The two PC's are connected as shown in FIG. 5. Lines 151-153 together represent the input line to the position amplifier 90 whose output HBPOS is a function of the relative position of the PE track with respect to the PCs. Whenever the PE track is at a point A (with respect to the PCs), only the top PC is the recipient of light, since light track area 155 is between it and the

LED, while all the light to the bottom PC is blocked off under these conditions. HBPOS is assumed to be positive as represented by 156. Conversely, whenever the bottom PC is sensing the light, such as when the PE track is at point K and area 157 is between it and the LED while light to the top PC is clocked off, the position signal is negative, as represented by 158.

The PE track pattern is designed and attached to the shaft 150 so that when point B is aligned with the two PCs the hammer bank 12 is exactly at the RIGHT position, and when point J is aligned with the PCs, the bank is exactly at the LEFT position. The distance between points B and J is the hammer stroke distance which is equal to the desired character spacing, e.g., 0.100 inch. Whenever any of points B, D, F, G, or J is aligned with the two PCs both PCs receive equal amounts of light and therefore the signal amplitude is zero. It is positive (or high) when the track is at any of points R, A, E or I and is negative (or low) at points C, G, K and L. Points R and L respectively represent positions of the track when the bank abuts against right and left bumpers, whose functions will be explained later. From the foregoing, it should be appreciated that as the bank moves between the RIGHT and LEFT positions (between points B and J) only three zero crossings of HBPOS occur. It is these three zero crossings which are converted by detector 82 into the three pulses 130 which are counted by detector 84.

From the foregoing description and particularly FIG. 5, it should be apparent that when the bank is at the RIGHT position (point B) or the LEFT position (point J), deviations of the bank to the right or left result in a positive or negative position signal, respectively. The positive or negative position signals when fed to the summing amplifier cause the power amplifier to drive the bank to the left or right respectively to reduce the position signal to zero. Thus, the position servo loop maintains the bank at the desired bank positions. To insure that the position signal is positive or negative when the bank is to the right or left respectively of each position, the track pattern has to be designed to produce an odd number of crossover points.

From FIG. 5 it is also seen that the zero cross-over points between positions such as points D, F and H are equally spaced between the two positions. Actually, due to their spacing each crossover pulse occurs after the hammer bank is moved  $\frac{1}{4}$  the stroke or distance between the two positions. When the hammer bank is moved from the LEFT position (point J) to the RIGHT position (point B), the third pulse occurs at point D when the hammer bank is  $\frac{1}{4}$  stroke distance from the RIGHT position. Conversely when moved from right to left the third pulse occurs at point H when the hammer bank is  $\frac{1}{4}$  stroke distance from the LEFT position (point J). Thus, the function generator resetting occurs when the hammer bank is  $\frac{1}{4}$  the stroke distance away from the position to which it is driven.

When the power to the printer is first turned ON the controller is in the position mode. However, the exact position of the bank is not known. The position servo loop may lock the bank at any of points B, F or J, i.e., at any point in which the position signal is zero with a positive polarity adjacently to the right and a negative polarity adjacently to the left. Since only points B and J represent desired bank positions, it is necessary to initialize the controller to drive the bank to either the RIGHT position (point B) or the LEFT position (point

J). The input unit 70 includes logic circuitry designed to automatically drive the bank to one of the desired positions. The position detector 78 is designed to sense to which of the two desired positions the bank is approaching or at which it is positioned to provide an appropriate output (BP) for use by the printer logic section 115. The input unit is designed such that the bank continues to move alternately between the LEFT and RIGHT positions until the integrity of position detector can be assured.

Attention is now directed to FIG. 6 wherein the input unit 70 is diagrammed in block form. The unit consists of a dual triggerable one shot, which together with related circuitry is designated by U106, a triggerable one shot U112 and a latch circuit consisting of two gates U108. The operation of the input unit may best be described in conjunction with FIG. 4. The initialization is started by a hammer bank move command HBM\* (line a) which is applied by the printer logic section 115 by driving line 116 low. In FIG. 4, this command is assumed to start at time  $t_r$ . When HBM\* is applied, i.e., line 116 goes low, U111-12, representing the output at pin 12 of U111 goes high. It triggers the retriggerable one shot 106 causing pin 13 (U106-13) to go high, as represented in line a1 in FIG. 4. This in turn triggers the other half of the dual retriggerable one shot 106 so that U106-5 goes high for a short duration, representing the move clock (HBMC) pulse 120 shown on line b.

U106-5 is connected to the direction flip flop, designated U103 in the function generator 72. Basically, the HBMC (pulse 120) switches the flip flop U103 from its previous state to its other state. As shown in FIG. 4, it is assumed that prior to  $t_r$ , U103 is set (see line C). Thus, at  $t_r$  it is reset. As a result, the function generator 72 output, HBCV ramps up (line d) thereby driving the bank to the left. For explanatory purposes, let it be assumed that at  $t_r$  the bank was initially locked at point F (FIG. 5). Therefore, as the bank moves to the left only two pulses 130 will be produced (see line J) as points H and j are crossed. The bank is driven past the desired LEFT position until it reaches a left bumper, represented in FIG. 5 as point L. The left bumper prevents any further leftward motion of the bank, even though the function generator 72 continues to provide the velocity command signal. The bank is assumed to reach the left bumper at time  $t_p$ . At time  $t_z$ , U106-13 times out. U106-4 going high at this time (see line a 2) triggers U112 so that U112-4 goes high (line b1). This is so since U106-4, having been low during the preceding time period, had set the associated latch circuit comprising of gates U108-8 and U108-6, which removed the reset level to U112.

When U112-5 goes high, it activates an Or gate U104 in the function generator 72 to reset both flip flops U101-5 and U101-9 in the function generator. These two flip flops when both are reset cause the integrator-amplifier 180 in the function generator 72 to ramp back to zero from its previous level. In the particular example, the voltage ramps down thereby allowing the bank to return from the left bumper toward the LEFT position during the ensuing position mode. The length of time that U112-5 is high is chosen so that after the HBCV reaches zero (line d) and the controller is in the position mode the controller remains in this mode long enough to drive the bank to the LEFT position, assumed to be reached at time  $t_p$ . The duration that

U112-5 is high represents a forced voltage reset pulse FHBR shown in line b1.

Although the bank is now (time  $t_p$  at a valid position (LEFT in this example), the status of the position detector is uncertain. This is true since the operation of the position detector (as described previously) is dependent upon the detection of three crossover pulses 130 during bank movements. Consequently, an additional HBMC 120 is generated at time  $t_q$  so as to initiate an additional bank movement. This is accomplished by U112-5 (line b1) going low while U111-12 is high which triggers U106-13 (line a2). U106-13 going high in turn triggers U106-5, the output of which is HBMC (line b).

For the LEFT to RIGHT bank movement initiated at time  $t_q$ , three crossover pulses 130 are produced before it reaches the RIGHT position just like in the normal operation. Thus, the output of detector 84 goes high at time  $t_r$  which resets the function generator 72 causing HBCV to ramp towards zero. At time  $t_s$  HBCV reaches zero and therefore HBPM goes high. It now activates the output unit 75. Since the output of detector 84 is high (line h) and since one shot U106-13 did not time out yet to activate U112-5, the output unit produces the HBCLK\* pulse to the printer logic section 115. The latter then sets line 116 at time  $t_r$  to high. This in turn resets U106-13 so that it cannot time out to trigger U112-5. Thus, the initiation operation is completed and the position servo loop holds the bank at the RIGHT position.

In the present invention, the on-time of U106-13 designated as D in line a1 is chosen to be greater than the period from the instant the bank move command HBM\* is normally received until the move is acknowledged through receipt of HBCLK\* by the printer logic and line 116 returns to high. The one-time of U112 designated D1 in line b1, is chosen to drive the bank during the initialization process from one of the bumpers to the adjacent desired position, first by the velocity signal which ramps back to zero, and then by the position servo loop.

It should be pointed out that the initialization process is independent of the position of the bank at the time the process starts or the state of the direction flip flop. In the foregoing, it was assumed that the direction flip flop was set prior to the initialization at  $t_r$ . Thus, the bank was driven to the left bumper. If the flip flop is reset prior to initialization, the first HBMC pulse drives the bank to the right bumper assumed to be at point R (see FIG. 5).

Attention is again directed to FIG. 6 in connection with which function generator 72 will now be described in further detail. The generator 72 in addition to direction flip flop U103 and gate U104-4 includes a left flip flop U101-5 and a right flip flop U101-9 and an integrator-amplifier 180. The integrator amplifier 180 which is basically a closed loop integrator circuit or comprised of a summing amplifier U115-1 and an operational amplifier U115-7. When the bank is at either the LEFT or RIGHT position both U101-6 and U101-8 are high, since both flip flops are in a reset state, and the output HBCV of circuit 180 is zero. When the bank is at the LEFT position, U103-5 is low and when the bank is at the RIGHT position U103-5 is high (see line c).

Assuming that the bank is at the RIGHT position as shown at time  $t_1$  in line f FIG. 4, U103-5 is high and U103-6 is low (see line c). Also both U101-6 and U101-8 are high since both flip flops were previously

reset, see lines c1 and c2. When the next HBMC pulse 120 is applied to initiate a bank movement, pulse 120 clocks both U101 flip flops. Since U103-5 is high, it sets the left U101-5 flip flop so that U101-6 goes low. U101-8 remains high. Also, the HBMC pulse toggles U103-5 so that U103-5 now goes low (after setting U101-5 to high and U106-6 to low).

Since U101-6 is low and U101-8 is high, U111-6 and U111-5 are high and low, respectively. When U111-6 goes high, a positive voltage is reflected at U115-2 while U115-3 is at zero volts. This imbalance of the equilibrium condition of the summing amplifier forces U115-1 to go low. This in turn sets up a charging path via R1 to the low level at U115-1 for integrating capacitor C1 which comprises the feedback loop of operational amplifier U115-7. As C1 begins to charge up the output at U115-7, which represents HBCV, begins to ramp up, as represented in line d by 124. HBCV continues to ramp up until HBCV, fed back to pin 3 of U115 via R2 equals the potential at U115-2. When this condition is established U115-1 goes to zero, terminating the charging of the integrating capacitor. Thus, HBCV remains at a constant level (125 in line d). When the third crossover pulse (130) is detected by detector 84 it activates via line 200 Nor gate U104 so that U104-4 goes low, clearing or resetting both U101 flip flops. Thus, U101-6 goes high, U101-8 remains high since it was previously in a reset state.

When U101-6 goes high, U111-6 goes low and therefore U115-2 returns to zero volts. Since the voltage at U115-3 is still high (equalized at the previous high potential of U115-2 during the ramp up), U115-1 goes high. This then sets up a discharge path via R1 for C1. Thus, HBCV ramps down until the voltage at U115-3 is equal to the zero volts at U115-2. This occurs when HBCV is back at zero volts, at which time the position mode is initiated.

The function generator 72 functions in an analogous manner when the bank is at the LEFT position and the move command HBM\* is received to move the bank to the right. When in the LEFT position, U103-6 is high. Thus, when clocked by HBMC pulse 120, the right flip flop U101-8 goes low. U101-6 remains high. When U101-8 goes low, U111-4 goes high and a positive voltage is applied at U115-3. Since U115-2 is at zero, the imbalance condition causes U115-1 to go high. This sets up a discharge path via R1 to U115-1 for C1. Consequently, HBCV at U115-7 ramps down. It continues to ramp down until the potential at U115-3 decreases to zero to equal the potential at U115-2. Thus, HBCV remains at a constant level. It remains at this level until U104-4 goes low again (when the third crossover pulse is detected) resetting U101-8 to high and therefore U111-4 to low. As a result, U115-3 goes to a voltage slightly more negative than zero volts. Since U115-2 is at zero volts U115-1 goes low. This sets up a charging path via R1 to thereby charge up C1. Thus, HBCV at U115-7 ramp up toward zero volts, at which time U115-3 is at zero volts as is U115-2. This causes U115-1 to return to zero thereby terminating the charging of C1 and HBCV remains at zero volts.

As shown in FIG. 6, U101-5 and U101-9 are connected to a Nand gate 201, which together with the output HBCV of generator 72 at U115-7 are applied to the level detector 74. As previously explained the latter's output, HBPM is high (line j) when HBCV is at (or near) zero volt and is low when HBCV is other than

zero volts. After the third crossover pulses both U101-5 and U101-9 are low since both flip flops are reset by U104-14 going low. Thus, the output of 201 is high. This output is shown to one input of a comparator 203.

Comparator 203 compares HBCV with zero volts as well as comparing the output of gate 201 with zero. If either of these inputs are sufficiently different from zero the output from the comparator is low. This output is HBPM, which when high indicates that the controller is in the position mode. As previously explained HBPM, when high, is used to enable switch 80 to enable to position signal HBPOS to reach the summing amplifier for the position servo loop. HBPM is also supplied to the output unit 75 which produces the move complete pulse HBCLK\* (see line l).

As previously explained HBCLK\* when received by the printer logic section 115 indicates that the bank movement is complete. Which position the bank is at is indicated by the BP level on line 100. In accordance with the present invention as previously pointed out HBCLK\* is produced only when the bank reaches one of the positions in a normal manner (as defined as having successfully detected three crossover pulses 130 during the bank movement). Note that HBCLK\* is not produced when the bank reaches one of the positions from one of the end bumpers during the initialization process. For example, HBCLK\* is not produced when the bank reaches the LEFT position at time  $t_p$ .

As shown in FIG. 3, HBPM which is the output of comparator 203 is applied to clock generator 76 which in essence is a one shot. It is triggered by 203 going high to produce a clock pulse HBDOS shown in line k, and applied to the clock gate 77. The latter is actually a three-input gate. If during the duration of HBDOS, U112-12 is high (which is the case as long as U106-13 did not time out) and the third crossover detector sensed the third pulse switches from low to high as shown in line h, gate 77 produces the HBCLK\* pulse. This is the case in normal operations. However, if during the move operation, such as during initialization, U112-5 is triggered (see FIG. 4, line b1 at time  $t_2$ ) U112-12 goes low. Thus, when HBPM goes high (line j) after  $t_z$  and before  $t_p$  even though clock 76 produces the HBDOS pulse (line k), gate 77 does not produce the HBCLK\* pulse (line l).

As previously indicated the crossover detector 82 responds to the position signal HBPOS from position amplifier 90 and produces a pulse 130 (line g) each time the position signal crosses zero in either direction. Thus, it can be implemented as a zero-crossing detector well known in the art. Detector 84 is in essence a counter which produces a high output (line h) after three pulses are counted by it. For explanatory purposes, it may be deemed to be reset to provide a low output (see line h) whenever HBM\* goes high.

As previously indicated the position that the bank is approaching or is located at is indicated by the BP output of detector 78 (line i). It is high when the bank approaches or is at the RIGHT position and is low when the bank approaches or is at the LEFT position. In simplest form, the detector 84 can be thought of as comprising a flip flop 210 and comparators 211 and 212 as shown in FIG. 7. FF 210 is clocked by the low to high transition of the output of detector 84. If the position signal HBPOS is below zero, comparator 211 provides a high output causing FF 210 to be driven to its set state so that its Q output which is BP is high. On the other

hand, when HBPOS is above zero, comparator 212 provides a high output causing FF 220 to be reset. Thus, BP goes low.

Attention is now directed to FIGS. 1 and 2. As previously explained the bank movement is achieved by means of the motor 64 which is driven by the output of the power amplifier 88 (see FIG. 3). Since the bank 12 is supported by the flex pivots 61 and 62 very little driving force is required. Also, since the distance between the two desired positions which is the stroke distance is only the character spacing typically 0.100 in. the distance which the bank has to be driven is very small. In practice, any small reversible motor can be used as motor 64. In one embodiment actually reduced to practice a voice-coil type motor or actuator was used as motor 64. As used herein a voice coil motor or actuator refers to a unit in which a movable member on which a coil is wound is located in a magnetic field. The motion of the movable member and its direction are a function of the current amplitude and direction of flow respectively.

An embodiment of such a voice-coil motor 64 is shown in cross-section in FIG. 8. The motor includes a member 230 which is connected to the bank end plate 51. Member 230 houses multi-turn multi-turn conductor coil 231.

The member 230 which is the moving part of the motor is supported between an upper magnetic structural member 235 and a lower magnetic structural member 238 which supports a pair of bar magnets 240 and 241. The magnet configuration produces a magnetic flux path, generally represented by dashed line 246. It extends across the gap between magnets 240 and 241 and the member 235, a gap in which member 230 with coil 231 are located. As should be readily apparent the motion of the member 230 in the plane in which it is supported is a function of the current and its flow direction in coil 231. As shown in FIG. 8, end plate 51 of the hammer bank 12 is connected to member 230. Thus, the member bank 12 is moved by member 230 of motor 64.

From the foregoing, it is thus seen that in accordance with the present invention, a printer is provided in which the entire hammer bank is movable under the control of the hammer bank controller. As described, the hammer bank after initialization is moved between two positions (RIGHT and LEFT). By spacing the positions a distance equal to the character spacing, each hammer in the bank may be positioned at either of two print stations. In the hammer bank the hammer spacing is twice the character spacing so that when the bank is at one position the hammers are aligned with half the print station, e.g., odd stations, and in the other position the hammers are aligned with the even stations. Thus, the number of required hammers is only half the number of printable characters per line.

Although the invention has been described with positioning the hammer bank at two stations, it should be apparent that the teachings may be modified to position the hammers at more than two stations and thereby further reduce the number of required hammers. For example, with three hammer bank positions and with a hammer spacing of three times the character spacing each hammer can be positioned successively at three print stations to reduce the number of required hammers to one third the number of characters per line. For three position controls the dimensions of the PE track pattern (see FIG. 5) may be modified so that

the distance between point B row representing the RIGHT position and point F equals a character spacing and the distance between point F and point J, now representing the LEFT position is equal to one character spacing. In such an embodiment only one crossover pulse will be produced between positions. It can be used rather than the third crossover pulse hereinafter discussed. In such an embodiment the position to which the hammer bank is driven may be determined in the printer logic section by counting the number of HBM pulses from the time of initialization rather than from the position detector.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.

The embodiments of the invention in which an exclusive property of privilege is claimed are defined as follows:

1. A hammer bank system useful in an impact printer of the type including a printer control section for controlling the printer operation, the hammer bank system comprising:

a movable hammer bank including a plurality of spaced apart individually actuatable hammers; drive means coupled to said bank for driving the bank in either a first direction or a second opposite direction; and

control means responsive to a hammer bank command signal from said printer control section for controlling said drive means to drive said hammer bank in said first direction, when the hammer bank is at a first selected position, to a second selected position, and to drive said hammer bank in said second direction, when said hammer bank is at said second position, to the first position, said control means including output means for applying a move complete signal to said printer control section when the movement of said hammer bank from one of the positions to the other in response to the hammer bank command signal is completed, said control means further include positioning means for providing an analog position signal of zero amplitude with respect to a reference level when said hammer bank is at either of said positions, said position signal amplitude being of a first polarity with respect to said reference level when the hammer bank is between said positions within a preselected distance from said first position, and is of a second polarity, opposite said first polarity, when the hammer bank is between said positions and within said preselected distance from said second position.

2. The hammer bank system as described in claim 1 wherein said control means includes velocity control means for controlling, in response to said hammer bank command signal, said drive means to drive said hammer bank from one of said positions to the other, first at an increasing velocity for a predetermined first period, followed by a constant velocity for a second period until said hammer bank is at said preselected distance from the position to which it is driven, and thereafter at a decreasing velocity during a third period so that when the bank velocity reduces to zero at the end of

said third period said hammer bank is substantially at said other position.

3. The hammer bank system as described in claim 2 further including velocity sensing means responsive to the hammer bank velocity for generating a velocity-indicating signal, and means for applying said velocity-indicating signal to said drive means to control the hammer bank velocity as a function thereof.

4. The hammer bank system as described in claim 1 wherein said control means include input means for generating a move clock pulse of a preselected duration upon receiving said hammer bank command signal from said printer control section, and said control means include function generator means responsive to said move clock pulse when said hammer bank is at said first position for generating an analog velocity signal which ramps up from a reference potential to a selected level at a selected rate in a first period, and remains at said selected level until said function generator means is reset, means for applying said generated velocity signal to said drive means to drive in response thereto said hammer bank in said first direction toward said second position, said control means including means for providing a reset pulse to said function generator means when the hammer bank is at said preselected distance from said second position to reset said function generator means whereby the analog velocity signal ramps back to said reference potential at a selected rate, so that when said velocity signal amplitude is back at said reference potential the hammer bank is substantially at said second position.

5. The hammer bank system as described in claim 4 further including in said control means velocity sensing means for sensing the hammer bank velocity and for providing a velocity-indicating signal related thereto, said means including amplifying means responsive to said velocity signal from said function generator means and said velocity-indicating signal for controlling said drive means to drive said hammer bank at a velocity which is a function of said velocity signal and said velocity-indicating signal.

6. A hammer bank system useful in an impact printer of the type including a printer control section for controlling the printer operation, the hammer bank system comprising:

a movable hammer bank including a plurality of spaced apart individually actuatable hammers;  
drive means coupled to said hammer bank for driving the hammer bank in either a first direction or a second opposite direction; and

control means responsive to a hammer bank command signal from said printer control section for controlling said drive means to drive said hammer bank in said first direction, when the hammer bank is at a first position, to a second selected position, and to drive said hammer bank in said second direction, when said hammer bank is at said second position, to the first position, said control means including output means for applying a move complete signal to said printer control section when the movement of said hammer bank from one of the positions to the other in response to the hammer bank command signal is completed, said control means further including input means for generating a move clock pulse of a preselected duration upon receiving said hammer bank command signal from said printer control section, and function generator

means responsive to said move clock pulse when said hammer bank is at said first position for generating an analog velocity signal which ramps up for a reference potential to a selected level at a selected rate in a first period, and remains at said selected level until said function generator means is reset, means for applying said generated velocity signal to said drive means to drive in response thereto said hammer bank in said first direction toward said second position, said control means including means for providing a reset pulse to said function generator means when the hammer bank is at a selected distance from said second position to reset said function generator means, whereby the analog velocity signal ramps back to said reference potential at a selected rate, so that when said velocity signal amplitude is back at said reference potential the hammer bank is substantially at said second position, said control means further including position sensing means for providing a position signal with an amplitude which is a function of the hammer bank position with respect to said first and second positions, said position signal amplitude being zero said hammer bank is at either said first position or said second position, is of a first polarity when said hammer bank is beyond said second position with respect to said first position, and is of a second polarity, opposite said first polarity, when the hammer bank is beyond said first position with respect to said second position, said position signal amplitude changing polarities through zero  $n$  times as said hammer bank is moved between said first and second positions,  $n$  being an odd integer not less than 1, means for producing a zero crossing pulse each time said position signal amplitude crosses zero, and means for counting said zero crossing pulses and for providing said reset pulse to said generator means when a selected pulse count is reached.

7. The hammer bank system as described in claim 6 further including means for applying said position signal to said drive means when said velocity command signal is back at said reference potential and said hammer bank is substantially at said second position to drive said bank to said second position and maintain it thereat.

8. The hammer bank system as described in claim 6 further including in said control means velocity sensing means for sensing the hammer bank velocity and for providing a velocity-indicating signal related to the sensed hammer bank velocity, said control means further including amplifying means connected to said function generator means and to said velocity sensing means for applying a drive control signal to said drive means to drive said hammer bank at a velocity which is a function of said velocity signal applied to said amplifying means by said function generator means and said velocity-indicating signal applied to said amplifying means by said velocity sensing means, and means for applying said position signal to said amplifying means only when said velocity signal is at said reference potential, whereby when said velocity signal is at said reference potential the drive control signal from said amplifying means is a function of said velocity signal, said position signal and said velocity-indicating signal.

9. The hammer bank system as described in claim 8 wherein  $n=3$  and said generator means is provided with said reset pulse when the count is equal to 3.

10. A system for use in an impact printer of the type including a controller which controls the printer operation, the system comprising:

a movable hammer bank including a plurality of spaced apart hammers;

drive means including motor means for moving said hammer bank so as to selectively position it at either a first selected hammer bank position or a second selected hammer bank position in response to drive signals, received by said drive means;

input means responsive to a hammer bank command signal received from said printer controller when said hammer bank is at one of said selected hammer bank positions for providing a hammer bank move pulse;

a direction flip flop switchable between set and reset states thereof, said direction flip flop being responsive to said hammer bank move pulse for switching from its previous state to the other state, said direction flip flop being in the set and reset state respectively, when said hammer bank is at said first and second positions;

resettable generator means coupled to said direction flip flop and responsive to the change of state thereof for generating when said direction flip flop switches from the set state to the reset state an analog hammer bank velocity command signal which ramps in a first direction from zero volt to a selected voltage level of a first polarity at a first selected rate, remains at said level until said generator means is reset and when reset ramps back to zero volt at a second selected rate, said generator means when said direction flip flop switches from said reset state to said set state generating said analog velocity command signal which ramps in a second direction, opposite said first direction from zero volt to said selected voltage level of a second polarity, opposite said first polarity, at said first selected rate, remains at said selected voltage level until said generator means is reset and when reset ramps back to zero volt at said second selected rate;

means for applying said hammer bank velocity command signal to said drive means to drive the hammer bank from said first position to said second position at an increasing velocity as said hammer bank velocity command signal ramps in the first direction, at a constant velocity when the hammer bank velocity command signal is at said selected level of said first polarity and to reduce the hammer bank velocity to zero as said hammer bank velocity command signal ramps back to zero volt, said drive means being responsive to said hammer bank velocity command signal when said hammer bank is at said second position to drive said hammer bank from said second position to the first position at an increasing velocity when said hammer bank velocity command signal ramps in said second direction, at a constant velocity when said hammer bank velocity command signal is at said selected level of said second polarity, and at a decreasing velocity when said hammer bank velocity command signals ramps back to zero volt;

position means for generating a position signal which is of zero amplitude when said hammer bank is at either of said selected positions, the amplitude being of a first polarity when the hammer bank is at any positions past said first position with respect to said second position, is of a second polarity when the hammer bank is at any position past said second position with respect to said first position, is of said second polarity when the hammer bank is between said positions within a preselected distance from said first position, and is of said first polarity when the hammer bank is between said positions within said preselected distance from said second position;

detector means coupled to said position means and responsive to said position signal for resetting said generator means when said hammer bank is moved from one of said positions to the other and is between said two positions at said preselected distance from the position to which it is moved, whereby said hammer bank velocity command signal ramps back to zero from said selected level at a rate so that when it reaches zero volt said hammer bank is substantially at the position to which it is driven;

means for applying said position signal to said drive means after said hammer bank velocity command signal ramped back to said zero volt to maintain said hammer bank at said position to which it was driven by driving it in a direction so that the position signal amplitude is zero; and

output means for supplying said printer controller with a move complete pulse when said hammer bank velocity command signal amplitude is back to zero volt and said hammer bank is at a position to which it was driven within a preselected period from the time said hammer bank command signal was received by said input means.

11. A system as described in claim 10 further including velocity sensing means for sensing the velocity of said hammer bank and for providing a velocity-indicating signal of an amplitude related to the hammer bank velocity and of a polarity related to the hammer bank movement direction, and amplifying means responsive to said hammer bank velocity command signal and to said velocity-indicating signal for generating as a function thereof a control signal for said drive means to control the hammer bank velocity and its direction as a function thereof.

12. The system as described in claim 10 wherein said system includes a first element positioned adjacent said first selected hammer bank position on the side thereof remote from said second position so as to limit the movement of said hammer bank past said first element, and a second element positioned adjacent said second selected position on the side remote said first position so as to limit the movement of said hammer bank past said second element.

13. The system as described in claim 10 wherein said printer controller is connected to said input unit by an input line, said printer controller supplying said move command signal by changing the input line from a first level to a second level, the move command signal being terminated by the input line returning to said first level, and said input unit includes a first one shot triggerable by the first to second level change on said input line for providing a first pulse which extends for a first dura-

19

tion, said one shot being resettable to terminate said first pulse when said input line returns to said second level before the end of the first pulse duration, a second one shot responsive to the start of said first pulse for providing said move clock pulse, and a third one shot coupled to said first one shot for providing a second pulse of a second duration upon the termination of said first pulse when said input line is of said second level, means for connecting said third one shot to said resetting means for resetting said function generator means at the start of said second pulse, and means for connecting said third one shot to said first one shot to re-trigger said one shot to supply said first pulse at the end of said second pulse, said first duration being greater than the duration required for said system to move said hammer bank from one of said positions to the other and for said printer controller to return said input line to said first level upon receiving said move complete pulse from said output means.

14. The system as described in claim 10 further including a position determined for sensing the position signal amplitude when the hammer bank is moved between positions and is within said preselected distance from either position, and for providing a position-indicating signal to said printer controller, said position-indicating signal switching to a first level from a second level when the hammer bank is moved from said first position and the hammer bank is within said preselected distance from the second position, said position-indicating signal switching to said second level

20

from said first level when the hammer bank is moved from said second position to the first position and is within said preselected distance from said first position, and connecting means for supplying said position-indicating signal to said printer controller.

15. The system as described in claim 10 wherein said position means includes means whereby as said hammer bank is moved between said two hammer bank positions, said position signal amplitude is zero  $n$  times where  $n$  is an odd integer and said detector means includes means for producing a crossover pulse each time the position signal is zero as the hammer bank is moved between two positions and further includes a counter for counting said crossover pulses and for resetting said generator means when the count in the counter is  $n$ .

16. The system as described in claim 15 wherein  $n=3$  and the  $n$ th pulse is counted when the hammer bank is moved between the two positions and said selected distance is substantially one quarter the total distance between the two positions.

17. The arrangement as described in claim 8 wherein said drive means include motor means comprising magnets for establishing a magnetic field, and coil means coupled to said hammer bank and located in said magnetic field and responsive to said drive control signal for moving, together with said hammer bank to which said coil means is coupled, at a rate in either of two directions with respect to said magnets as a function of the magnitude and polarity of said drive control signal.

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