ABSTRACT: For line printers of the type wherein a web of paper is imprinted by impact by a line of hammers on one side of the sheet which drives the paper against selected ones of type faces driven rapidly and continuously past the printing line behind the web, a simplified hammer module is disclosed. The module embodies so-called free-flight hammers which are thrown against the web by electromagnetic actuators. The hammers are guided by simple rounded grooves in which they rest. Simple mild steel actuator arms are shown to have necessary mechanical and magnetic properties to link electromagnets and hammers. Electromagnets are arranged in two rows whereby alternate hammers are thrown by straight and offset actuator arms, achieving a module for 80 hammers with pica spacing all of which is below the print line for quick reading accessibility.
HAMMER MODULE FOR HIGH-SPEED LINE PRINTER

This invention, generally, relates to high speed printer hammer modules of the type used in printers used with data-processing equipment, and more particularly it concerns a print hammer module particularly adapted to operate at the information capacity of an ordinary telephone line.

In high speed printers of the type aforementioned, a moveable hammer carrier supporting a plurality of type faces is moved continuously past a print line at a high rate of speed. A printing medium, such as a web of paper, is fed incrementally, step by step past the print line, and an aligned array of print hammers is arranged for impact printing along the print line, one hammer being provided for each print position. The resulting printed copy is arranged in horizontal rows and vertical columns, one column for each hammer and print position. The type carrier may be a drum rotating on a horizontal axis with a complete font of characters arranged in a ring around the drum for each printing position. For pica typewriter characters, columns are spaced 10 to the inch, and a drum about 3 inches in diameter will accommodate 64 characters of an “upper case only” font, while somewhat less than a 6-inch diameter may accommodate a 128 character font of upper and lower case characters.

Alternatively, the type font may be carried on a belt or large wheel which traverses horizontally along the print line. Travelling either way, vertically or horizontally, all of the characters must pass each print position in each cycle time of the printer. Printers of this type may operate at a speed of 5 to 10 lines per second and higher. Given 80 pica characters per standard line, and 64 characters to a minimum font, the minimum speed of the type relative to the web is about 15 inches per second. If smears are to be limited to one one-hundredth of an inch, then impact between hammers and the moving type faces must last for only a fraction of a millisecond. To minimize smearing of the copy, various expedients have been adopted to accelerate and control the motion of the hammers. A further alternate approach is represented by U.S. Pat. No. 3,285,164 to Malavazos wherein a horizontally driven chain carries, not individual type fonts, but print wheels, each having a different character repeated 6 times around the wheel which is driven by an endless rack and pinions to have rolling contact at the points where the impressions are made. Print hammer modules embodying the present invention may be employed in place of hammer modules of the prior-art in conjunction with each of these various kinds of machines.

Printers of the types described above operating at the higher speed range of 10 lines per second and more, and 128 characters to the font, represents an information flow rate of 5,600 bits/second or more. This high information flow rate is required to approach the power of a modern digital computer to generate date; but is several times the information handling capacity of ordinary telephone lines and its terminal equipment.

Because of the complexity required to achieve such high data rates, line printers of the type described are very expensive. Of considerably lower cost are various teletypewriters and tape-controlled typewriters which are capable of speeds up to the order of 40 characters per second, compared to 800 characters per second of the line printers. These latter machines are not cheap either. Moreover, they fall far short of matching the information capacity of a minimum quality telephone circuit.

The principal object of the present invention is to provide a simple, inexpensive print-hammer module whereby to provide a line printer with capacity to transcribe the maximum information rate of an ordinary telephone line, yet to cost no more than much lower speed automatic electric typewriters.

An essential feature of a line printer is its memory in which it accepts a batch of information from a source, which may be a telephone line. The memory is then ready to be read at times pulses to the several hammers during one cycle of the type carrier. Meanwhile, the memory must continue to accept the next batch of copy (which may amount to a line, or a fraction of a line) while the previous batch is being printed. This memory may be implemented in various ways, but one implementation requires a six-or seven-bit shift register for each column of type. With the advent of integrated circuit shift-registers, and other advanced memory techniques, the electronic memory is reduced to a minor portion of the cost of the printer. Once the mold is made, plastic molded print rollers are relatively inexpensive. The principal remaining contributor to the cost of such a printer, and clearly the most critical portion, principally limiting performance is the print module assembly of the hammer module, the assembly of 20 to 160 (typically 80) similar electromechanical mechanisms, spaced only one-tenth of an inch apart, on the average, along the print line.

Various types of hammers have been tried in such line printers, including hammers driven by hydraulic, pneumatic, and magnetic forces. In some mechanisms, the hammers are pivoted in the manner of conventional typewriter keys, while in others, a so-called free-flight hammer is employed.

A hammer module of the type wherein the hammer faces are on the ends of magnetically operated actuator arms is disclosed in Potter U.S. Pat. No. 3,349,696. Since it is often necessary or desirable to vary the thickness of paper or carbon on paper, the free-flight type hammer is preferred wherein the hammer is struck or thrown by the actuator, the armature can bottom before the hammer strikes, thus keeping efficiency higher than if adjustments were required to enable the armature to bottom for varying paper thicknesses.

The free-flight hammers must be guided in the flight to insure that they will strike the rotating drum at precisely the correct places on the drum periphery. Also, the hammers must be returned to their rest position between the next print cycles. U.S. Pat. No. 3,145,650 to Gerard C. Wright discloses a sophisticated arrangement for such guidance, to overcome difficulties in the prior art wherein each individual hammer in a supporting channel or guide so that upon the impact of the actuator the hammer moves forward to effect a printing stroke. Upon the completion of this stroke, the hammer returns to its original or rest position within the guide by spring means. Due, however to varying frictional forces between the hammers and the guides, the flight of the hammer, either in its forward motion toward the drum or in its spring actuated motion back to its rest position, is often erratic. Such erratic action results in variations in flight time and consequently irregularity of the print line. Cleaning such channels is a time-consuming and expensive procedure, and the fabrication of the channels requires very accurate machining to insure proper fit.

It is an object of the present invention to provide a simplified hammer guide arrangement which avoids the above-mentioned shortcomings of the prior art with a compact and simple hammer guide arrangement which is inexpensive to manufacture and easy to clean and more tolerant of lint and grit.

It is a further object of the invention to provide a simple and reliable structure to hold and locate hammers and actuators in correct alignment one with other, and a further objective to provide simple spring means to return hammers and actuators to their rest positions.

It is a further object of this invention to provide an improved arrangement of actuators whereby they may be closely spaced, yet occupy only one side of the print line so that the emerging copy may be read not more than 1 second after printing.

A feature of the invention by which the above objects are attained is a one-piece guide block for hammers and actuators. Another feature is a one-piece spring comb by which a group of hammers and actuators are returned to their rest positions.

A further feature of the invention is a simplified actuator arrangement providing for alternate straight and offset actuators whereby to provide spacing of one-fifth of an inch between
coils on each of two solenoid assemblies, one for the straight actuators and one for the offset actuators, while having only one-tenth of an inch on centers between actuator throwing arms and hammers.

Other features of the invention will appear in the description of the invention below with reference to the accompanying drawings in which:

FIG. 1 is a view, partly in section, illustrating the relative situation of the printing drum, hammers, actuators, mounting means for the hammers and actuators, etc. and

FIG. 2 is a cutaway perspective view of the preferred embodiment of the invention.

As shown in FIG. 1 a drum 10 is provided which rotates to carry the type faces 12 upward past the hammers 14. In the preferred embodiment the standard ASCII (63 character plus blank) font is employed. Each of the hammers 14 is normally held in its rest position away from the drum by a return spring leaf 16 which engages a recess in the form of a groove 17 in the hammer. Alternately the hammers are engaged at their tail ends 18 by straight actuators 20 and offset actuators 22. Straight and offset actuators have identical throwing arms 26 which are thin pieces of ordinary cold-rolled steel, for simplicity cut from flat stock 0.032 inches thick, thick enough not to buckle, yet thin enough to be riveted in place to fit in the available parallel relationship toward the upper end from a maximum depth of the cantilever beam of 0.312 inches at the pivot pin 30 to a minimum depth of one-sixteenth inch. The actuators, hammers, and return springs are all mounted on a hammer and actuator guide block 40. This block, which preferably is formed from a single piece of metal or plastic has a mounting flange 41 (shown in FIG. 2) at each end from which it is supported in parallel relationship to the drum 10. A hammer mounting channel 42 is formed at the top 43 of the block 40 which is just over 8 inches wide, and somewhat over one-eighth inch deep. At the bottom of this channel there are 80 near semicylindrical grooves 44 spaced one-tenth inch on centers. A set of the hammers 14 may be dropped into this channel and tend to be evenly spaced by these grooves. Hammers are only slightly less than a full column width (preferably 0.095 inches). They are simple bars, the height being determined by the height of the letters in the type font. The head end of the hammer bar provides the striking face which must be large enough and proportioned to cover all of the characters in the font. The top is flat, to bear against the type face, and which retains the set of hammers in the channel 42. The bottoms of the hammers are curved hemicylindrically on a 0.0475 inch radius, half the hammer width. A slot 48 extends the width of the channel 42 intercepting the grooves 44 and cutting into portions carrying respectively the head and tail ends of the hammers. The slot 48 provides a slot, which may enter the channel 42 to drop down out of contact with the hammers 14.

The block 40 has a face 50 facing the impression sheet 52, and extends downward about 2 inches and parallel to the drum axis. Generally parallel to the face 50 is the back 54.

At the bottom of the block and extending outward from the back is a foot 60 having large toes (not shown) on each end and 79 small toes 62 separating and guiding the 80 actuators. A notch 64 on the bottom of each of the toes provides an opening through which the pivot pin 30 passes and is located. The pivot pin is retained in place by three retainer fingers 68, which are fastened to the foot 60, one at each end and one in the middle.

From the pivot pin 30, an armature arm 90 extends downward for each of the straight actuators, while the armature arm 90e extends generally horizontally out from the foot 60. Each of these arms carries an armature piece 92 of mild steel or other material of high magnetic permeability. Opposing each of these armature pieces is an electromagnet. Two sets of cores 96 and 96e are provided. In each set, the electromagnets are spaced on centers by twice the column width, and thereby one set of magnets may be placed in opposition to the straight armature arms, and one set of magnets may be placed in opposition to the offset armature arms. Since the force of the magnets is limited by pole face area, this arrangement allows for a more conservative magnet design, using simple mild steel cores. Ordinary magnets would be limited to one column width. This kind of staggered arrangement has been favored in the prior art as represented by the patent to Wright; but in the prior art the actuators have been distributed above and below the print line. In arrangements such as shown in Wright, the print line is hidden behind the hammer modules with the result that there is a delay after a line is written before it can be read.

The cores 96o are of a U-shaped contour (so-called C-cores) with windings 97 on two long legs and with retention notches 100. The cores may be laminated or a single piece of 0.13 gage, (0.0897 inches thick) mild steel. Cores are preferably 1.650 inches long, by 0.781 inches wide with a slot between the legs about 0.16 inches wide and 1.16 inches long.

The cores are assembled to a channel 102 having end fittings 104 by means of a casting resin 105, preferably an epoxy formulation. The assembly of cores, and mounting channel comprise a core assembly bar. The bar 106o containing the cores 96o and the bar 105s containing the cores 96s for the straight actuators may be identical and interchangeable, turning one end for end to replace the other. A pair of plastic spacers, to take the windings 97 for each core. Preferably these spools are wound in series on a mandrel, then slipped over the core legs. A total of 300 turns of 0.30 enamelled magnet wire in three layers is appropriated. Molded integrally with the spool 107 are a pair of contacts 109 to which the ends of the winding are attached, leaving the pins projecting outward from the core assembly bars in 0.10 inch spacings. Individual windings may be replaced if necessary without destruction of a core assembly bar.

Two identical end frames 110 are provided which support the ends of the guide block 40 which carries the hammers 14 and the actuators 96s and 96o. To maintain accurate relationships between the hammers and the print roller, and between the actuators and their respective core assembly bars, the roller and core assembly bars are carried on the same end frames 110. The bearings 112 for the print roller are retained by pillow blocks 114.

A very simple arrangement of return springs is provided. A spring comb 116 is provided. Fastened by screws to a spring boss 118 extending across the block 40 between the grooves 44 and the foot 60, the comb has as long teeth extending upward the leaves 16 to engage each of the grooves 17 in the tail ends of the hammers 14 and serve as hammer return springs. Actuator return springs 128 are provided by shorter, and therefore stiffer, teeth extending downward to engage spring return abutments 130 at the front of each throwing arm about three-eighth inch from the bottom.

The rest position of the hammers 14 is against the actuator throwing arms, while, in turn, the rest position of the actuators is determined by the contact of stop abutments 134 and 134o at the ends of the straight and offset armature arms respectively with stop bars 135 and 136 respectively, fastened to the end frames.

Connections between the windings 106 and the external circuitry are by way of the connector pins 107, 108 (one of each per core) mounted to the spoolls 107. The pins, spaced 0.10 inches apart are engaged by connectors (not shown). One connector is provided for each 10 cores. Successive characters may follow rapidly in time as a given line is printed, then printing must be stopped while the paper is indexed to the next line. This can be accomplished in about 20 milliseconds, less than the time for a quarter turn of the print drum. If each and every one of the 63 characters in the font were to appear on each line, then at least 1¼ turn of the print drum would be required for each line of copy. If the line rate is synchronized with the drum rate, then, also at least 1¼ turn is required per line of copy. Fortunately the copy to be printed does not call upon all of the characters with equal frequency. Letters, numerals, punctuation, and special symbols are grouped so that, ordinarily, one of these groups is not called for in a line, so
that paper may be indexed as the characters of the unused group pass the print line. The memory logic may be arranged so that when all of the characters in a line are printed, this fact is indicated to trigger the paper advance mechanism. Once a hammer has been thrown, it cannot be called upon for a subsequent throw until at least the time required for paper advance has elapsed. Thus, while the hammer must strike quickly (in the order of a millisecond), it may be relatively leisurely in returning to its rest position.

The hammers are returned to rest position primarily by rebonding from the elastic print drum. Assisting the rebound, the spring leaves 17 insure that at the start of actuator action, the hammers are in contact with the actuators. In asynchronous operation, printing of a line may begin at any position of the print roller. Suitable circuitry, which may include a photoelectric pickoff and apertured disc (not shown) rotating with the print roller, provides electrical impulses timed to coincide with the progression of the characters on the print roller past the print line. A particular time delay corresponds to each character. The shape and duration of the current pulse to the electromagnets is not critical; but for timing the shorter the pulse, the better. If the pulses are too short, then voltages and currents become unacceptable high. For simplicity, a solid-state switch circuit closes for just 2 milliseconds. For a 63-character font at five printed lines per second this is only slightly less than the character time.

Because of armature inertia and core inductance, the current increases and the airgap in the magnetic circuit decreases during an actuator cycle until at the instant when the armature bottoms in contact with the pole faces 144, 146, the inductance, current and force are maximized. Because of the rapid buildup of force, there is some bending of the throwing arm at the instant the armature bottoms. Thereafter the tip of the throwing arm continues to move forward as the bending stress is relieved, and the resulting hammer speed continues to increase until the arm is relaxed, at which point, the hammer separates from the actuator and continues in relatively free flight to strike the paper. Because of its inertia, the throwing arm tends to follow through, then whip back assisted by the return spring leaf 128 and the termination of magnetizing current.

Depending upon the copy to be transcribed, any number of hammers from zero up to all 80 may be called upon to strike at a given instant, the average number is small, but there is a substantial probability that a line of copy may contain a great many zeros; or a dashed or dotted line may be called for. To avoid having such copy calling for simultaneous operation of all 80 hammers, the print roller is commonly segmented into 20-column sections, with the characters of the sections staggered one with respect to the next. The power supply for the hammer electronics may then be made marginal for the case when 80 hammers are called for, with the probability negligibly small that more than 40 hammers would be called for at a time. This problem does not arise with printers in which the type carrier is a chain or belt which carries the type faces horizontally along the printing line.

We claim:

1. For printing a sheet with character positions arranged in regular lines and at least eight columns across said sheet a hammer module for a high-speed printer, of the kind wherein characters are selected from a type carrier circulating continuously behind said sheet carrying type faces for each of the characters of a font to present at each character position on a print line different ones of said faces in successive character times, so that by striking the paper from the front with hammers arranged in a line across said sheet, the blow of each hammer being timed to be coincident with the passing of a character position by the desired character for that position, the several hammers being variously timed to effect the printing along said print line of a predetermined line of copy within a single circulation of said carrier, the combination characterized by

a. a plurality of such hammers, one for each said column, each of said hammers comprising a rigid bar having a head-end striking face adapted to press upon impact against the type face of the selected character, said hammer being of a width closely approaching, but not exceeding, the width of said column, having flat, vertical, and parallel sides, and a cylindrical bottom surface, whereby said hammers when situated side-by-side have freedom to slide one against the next, but are restrained by interference each with the next against excessive tipping, each said hammer having a tail end adapted to abut the throwing arm of a corresponding hammer actuator,
b. mounting means situated at the ends of said module,
c. an equal plurality of actuators,
d. a hammer and actuator guide block, said block having end parts attached to said mounting means and a central portion, said central portion having a face, situated facing and generally parallel to said sheet, parallel to said print line, a back generally parallel to said face, a top, extending generally perpendicular to said face and substantially coplanar with said print line, the upper surface of said top being figured by a sequence of parallel rounded grooves extending perpendicular to said sheet and spaced on centers by the width of said columns to support and space said hammers, and said block having a foot with toes extending outward from said block below and generally parallel to said grooves and centered between them, parallel and vertical sides of said toes guiding guiding slots for said actuators, said toes having bearing openings to support a pivot pin for all said actuators,
e. a pivot pin passing through said openings,
f. each of said actuators comprising a piece of metal having uniform thickness to fit between said toes having a depth sufficient to be substantially rigid in rotation about said pivot pin, having a throwing arm portion tapered from said pivot pin to a thin end to abut the tail end of said hammers, passing between said toes in said slots and pivotally mounted on said pivot pin,
g. said actuators comprising a set of straight actuators and a set of offset actuators, said offset actuators being alternately intermixed between said straight actuators, each said straight actuator having a straight armature extending generally parallel to said sheet below said pin as an extension of said throwing arm, having a soft-magnetic armature piece fixed to a side thereof,
h. each of said offset actuators having an offset armature extending generally perpendicular to said sheet and perpendicular to said straight armatures, having a soft-magnetic armature piece fixed to a side thereof,
i. a first electromagnet assembly comprising a plurality of electromagnets each having a core and a magnetizing winding on said core, said cores being assembled parallel, spaced apart on centers by twice said column width and presenting a first working surface in which pole faces of said cores are regularly arrayed,
j. a second electromagnet assembly substantially identical to said first electromagnet assembly having a second working face,
k. said first electromagnet assembly being attached to said mounting means to situate said first working face in close opposing relationship to said armature arms of said straight actuators, each one of said first surface pole faces being in operable opposition to a corresponding one of said armature pieces, and
l. said second electromagnet assembly being attached to said mounting means to situate said second working surface in close opposing relationship to said offset armature arms, each one of said second surface pole faces being in operable opposition to a corresponding one of said armature pieces.

2. A printing mechanism comprising
a. a hammer module as defined by claim 1 wherein said mounting means comprise a pair of end frames generally parallel and extending away from said sheet and downwardly from said line of text to a machine frame and
b. a type-carrying drum rotatably supported on said end frames and continuously rotatable behind said sheet containing for each of said columns a font of type arranged in a ring around said drum.

3. A hammer module as defined by claim 1 wherein said metal is mild steel.

4. A hammer module as defined by claim 3 in further combination with a flat spring piece cut to form a hammer return spring comb having teeth in the form of leaf springs each adapted to engage at its tip the tail end of a corresponding one of said hammers, the body of said piece being fastened to said back above said toes.

5. A printer comprising
a. a hammer module as defined by claim 4 wherein said mounting means comprise a pair of end frames generally parallel and extending away from said sheet and downwardly from said line of copy to a machine frame and
b. a type-carrying drum rotatably supported on said end frames and continuously rotatable behind said sheet containing for each of said columns a font of type arranged in a ring around said drum.

6. A hammer module as defined by claim 1 wherein said grooves are divided by a slot cut into said block top parallel to said print line into front and back portions, in further combination with a spring piece cut to form a hammer return spring comb having teeth in the form of spring leaves each said leaf adapted to engage at its tip the tail end of a corresponding one of said hammers, the body of said piece being fastened to said back above said toes, and wherein each of said hammers has a recess at its tail end to engage one of said leaves.

7. A hammer module as defined by claim 6 wherein said metal is mild steel.

8. A hammer module as claimed 1 in further combination with a straight stop bar maintained by said mounting means parallel to said print line in opposition to stop abutments on said straight actuators, whereby to establish the rest position of said actuators.

9. A hammer module as defined by claim 8 wherein said metal is mild steel.

10. A hammer module as defined by claim 9 in further combination with a spring piece cut to form a return spring comb having upward extending teeth in the form of spring leaves each said leaf being adapted to engage a recess in the tail end of a corresponding one of said hammers, and having downward extending teeth situated to engage return spring abutments on corresponding ones of said throwing arms, the body of said piece being fastened to said back above said toes.