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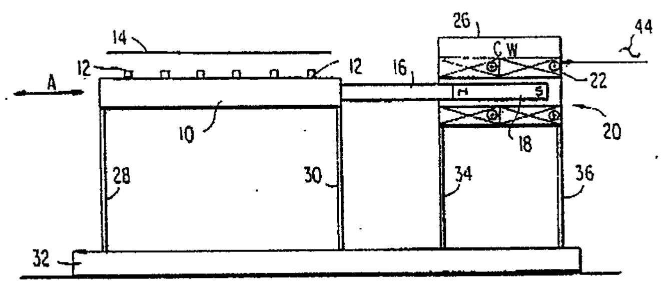
(54) Balanced print head drive mechanism.

(57) The shuttle print head of a matrix printer carries a plurality of printing elements and is supported by leaf springs on the printer frame. The print head is fixed to the movable core of a linear electric motor whose driving coil is also supported on the frame by leaf springs. The masses of the print head array and coil are made equal to form a balanced mass/spring system having a natural resonant frequency of oscillation of sinusoidal motion. The resonant frequency is chosen to correspond to a desired print rate. The drive coil is energized with alternating current at the resonant frequency in order to maintain the sinusoidal oscillation of the print head array at the required amplitude of oscillation. Selective energization of the printing elements effects selective printing of indicia at equal space column locations.



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BALANCED PRINT HEAD DRIVE MECHANISM

Background of the Invention

Field of the Invention

This invention relates generally to an improved print head drive system for a shuttle dot matrix type printer and, more particularly, to such a drive system in which the print head and drive mechanism have equal masses and are mounted on springs to provide a mechanically balanced system wherein the print head array oscillates or reciprocates with a sinusoidal motion at a resonant frequency corresponding to that of the desired printing rate determined from throughput requirements and character geometry.

Description of the Prior Art

As the requirements for higher throughput, i.e. print speeds, for a matrix printer increase, the prior art mechanisms for driving the print head array become more inefficient in attempting to produce a large displacement at a stable frequency. At these higher speeds, the forces required to accelerate and decelerate the print head array would be rather large if one were to use the prior art mechanisms which would thus require correspondingly large drive motors and/or expensive bearings.

In an attempt to provide more efficient drive mechanisms for matrix printers, others have proposed relatively complex mechanisms in which various elements of the printer are mounted on springs. More specifically, in U.S. Patent No. 4,127,334 there is disclosed a matrix printer in which the print head is mounted on the printer frame by E-shaped springs. The print head is reciprocated by a motor via a mechanical linkage, and a weight is spring-mounted on the frame to suppress undesirable vibrations; however, there is no disclosure of reciprocating the print head at the natural resonant frequency of the system.

Also, in U.S. Patent No. 4,306,497 there is disclosed an attempt to provide a dynamically balanced dot matrix printer wherein the print head is connected by E-shaped plate springs to a balancing mass which, in turn, is connected by similar springs to a base structure; furthermore, the print head is specifically driven at a frequency other than the mechanical resonant frequency of the system.

In U.S. Patent No. 4,227,455 there is disclosed a complex, leaf spring suspension system for a carrier on which a plurality of printing elements are mounted. However, the oscillating carrier is connected by leaf springs to an intermediate frame which, in turn, is connected by leaf springs to a main frame. Furthermore, even though this system is driven at resonance, the system does not employ a counterweight which forms a balanced mass system; instead, undesirable vibrations are eliminated by a method wherein the mass of the main frame is made very large relative to the oscillating carrier, thereby reducing the amplitude of undesirable vibrations caused by acceleration and deceleration forces.

Furthermore, the Hewlett Packard Company has announced a Model 2608A dot matrix line printer wherein print hammer assemblies are mounted on a core bar which is driven back and forth by a voice coil type linear motor, and wherein both the core bar and the linear motor housing are attached to the printer casting by stiff flexure springs; however, there is no indication that the system is balanced by a counterweight or otherwise, or that the core bar is driven at the natural or resonant frequency of the system.

Summary of the Invention

Thus, the broad object of the invention is to provide an improved print head array drive system for a shuttle matrix printer wherein a resonant spring mass system is used in conjunction with a simple reciprocating drive device to obtain a large oscillatory displacement of the print head at a stable oscillating frequency.

Another object of the invention is to provide such an improved drive mechanism wherein the print head and drive device form a balanced mass system which is driven to oscillate with sinusoidal motion at the system's natural or resonant frequency corresponding to a desired print rate.

A more specific object of the invention is to provide such an improved drive mechanism wherein the print head includes the core of a linear motor which is energized by sinusoidal alternating current at the resonant frequency corresponding to the desired print rate, and wherein both the print head and the motor coil are mounted on leaf springs fixed to the frame of the printer.

A still more specific object is to provide such an improved drive mechanism wherein the core comprises a permanent magnet, and wherein a counterweight is added to the coil to make the masses of the print head and coil equal.

Brief Description of the Drawing

FIGURE 1 is a schematic diagram illustrating the principle of operation of the preferred embodiment of the invention,

FIGURE 2 is a schematic diagram of a print head array drive mechanism including the preferred embodiment of the invention,

FIGURE 3 illustrates schematically the manner in which the velocity information from a velocity sensor is converted into action signals for application to effect printing by the print heads,

FIGURE 4 illustrates graphically how sync pulses for generating print actuation signals are related to print head displacement, and

FIGURE 5 illustrates graphically in expanded form the relationship between equal dot column positions on the print medium and the time of actuation of print actuators.

Detailed Description of the Preferred Embodiment

FIGURE 1 is a schematic diagram illustrating the principle of operation of the preferred embodiment of the invention. A shuttle print head 10 comprises an array or plurality of printing elements 12 which are shown opposite a line of print 14 which, typically, would be on an incrementally driven section of paper backed by a striker bar or rigid backstop. During printing, the print head 10 is reciprocated or oscillated in the directions indicated by the arrow A. In one embodiment, to be described in further detail, the printing elements when selectively energized impact the paper through an inked ribbon to produce printed indicia at equally spaced column locations on the record medium or paper.

Print head 10 is fixed to an aluminum rod 16 which, in turn, is fixed to a permanent magnet 18 which forms the movable core or armature of a reciprocating linear drive motor 20 including a drive coil 22 which is energized by an alternating current signal 44 having a frequency equal to one of the above noted resonant frequencies corresponding to a desired print rate. A counterweight 26 is fixed to the coil 22 so that the mass of the coil and counterweight is equal to that of the print head array assembly including print head 10, rod 16 and permanent magnet 18.

Print head 10 is supported by a pair of leaf springs 28 and 30 which are fixed to the frame 32 of the printing apparatus, and the print head drive coil 22 with counterweight 26 is also supported on a pair of leaf springs 34 and 36 fixed to the frame 32.

Leaf springs 28, 30, 34 and 36 are identical, constrain the print head array and coil to roughly linear motion, and negate the need for the linear or rotary bearings of the prior art. There is only a slight pulling back of the print head from the paper as the print head increases in displacement from the rest position, but at all times the print head array remains substantially parallel to the paper. Such a spring configuration eliminates contact wear mechanisms, and with proper design the life of the springs can be very long. The springs are tailored so that their stiffness, when combined with the print head mass or the coil/counterweight mass, produces a resonant spring/mass system having a natural frequency which matches the required oscillating frequency of the print head array. In other words, if either the print head or coil/counterweight were manually pulled back and released, each would naturally vibrate at the correct fundamental frequency. The advantage of such a mass-balanced, mechanically resonant spring mass system is that minimal external force is required to accelerate or decelerate the print head during oscillation thereof. The minimal input energy required is that which is necessary to replace air resistance losses, print wire drag losses, and spring losses in order to maintain sinusoidal motion of the print head. With such a balanced system, the print head and coil oscillate at the system's fundamental resonant frequency, but exactly opposite in phase with each other, thereby eliminating or minimizing any undesirable vibrations which would otherwise occur because of the oscillation of the print head.

FIGURE 2 is a schematic diagram illustrating the manner in which the preferred embodiment operates within a matrix printer. Corresponding elements in FIGURES 1 and 2 have the same reference numerals. Upon energizing the coil 22 with sinusoidal alternating current having a frequency equal to the preselected natural frequency of the system, the coil and permanent magnet 18 start to vibrate with oscillations of increasing amplitude. As the amplitude of the oscillations, i.e. the displacement of the print head array, reaches the desired level, a feedback system senses and holds the proper amplitude. As the losses take energy from the system and the amplitude tends to decay, the feedback system applies more energy to the coil to correct further losses, thereby maintaining the sinusoidal motion with the desired amplitude. Since the print head assembly 10 and motor 20 are of the same mass and undergo the same displacement, the system is balanced, whereby the print head array and coil 22 naturally vibrate at the correct frequency, the coil supplying only sufficient energy to "tickle" the system to maintain the sinusoidal motion at the system's resonant frequency. The input energy is minimal, because the inherent kinetic energy of the system is stored and used again, rather than being absorbed or dissipated and then supplied again as required.

Since the system is a simple balanced spring/mass system oscillating with sinusoidal motion at the natural resonant frequency of the system, the position, velocity and acceleration of the print head array are all interrelated by very simple equations which permit the use of only a simple velocity feedback system. For example, a velocity sensor 40, which may be a coil surrounding a permanent magnet mounted on a stud fixed to the print head, produces a signal v, whose voltage is continuously proportional to the print head array velocity, to generate the necessary information using the relationship between velocity and position for sinusoidal motion. If this relationship can be properly maintained, the need for an accurate and expensive position detection system can be eliminated. This velocity analog signal continuously indicates the velocity (and, by calculation, the position) of the print head 10 and is fed back via line 41 to a servo system 42 for continuously adjusting or tickling the energy input to the coil 22. For example, the feedback signal v may be applied to a comparator CF together with the reference signal from the AC source 24 to produce the motor drive signal 44 required to replace losses and maintain the sinusoidal motion of the print head array at the resonant natural frequency of the system. The level of undesired vibration of this system is very low since the shuttle print head array reacts directly against a counterweight through the connecting frame 32 rather than being tied to a side frame through a motor and link.

As shown in FIGURES 2 and 4, the velocity signal v is also fed to a sync pulse generator which produces a sync pulse when the shuttle is at maximum left and maximum right, i.e. at the zero crossing points of the signal when velocity = 0. This sync signal is sent to a microprocessor 46 which produces an ENABLE command at the proper time to enable the printing process, i.e. when the printing elements 12 are positioned over their proper print positions.

According to FIGURE 3, there is shown schematically the manner in which the velocity information available from the sensor 40 is converted in a sync generator 50, into sync pulses which occur at the zero crossings of the velocity characteristic of the shuttling print head array. Zero crossing detectors, of course, are well known in the art. The sync pulses available from sync generator 50 are applied to a sinusoidal time pattern signal generator 51 which contains microprocessor 46. This generator 51 produces enabling signals which allow print information from print information source 53 to be loaded into gating logic 52. After the last piece of information is transferred, the gating logic automatically allows energization of the correct print actuators. The information from source 53 constitutes the signal information representing the individual dots forming a dot matrix character to be printed, as well known in the art. The individual gates in gate array 52 respond to the enabling signal available from generator 51 on lead 55 to enable print information from source 53 to be applied at the appropriate time via gate array 52 to the selected printing elements 12 on print head 10. In one embodiment each printing element 12 comprises a print coil or actuator 56 and an associated printing stylus or wire 57. When selectively energized by a signal from gate array 52, the associated print wire 57 is driven by the magnetic force established by printing coils 56 to impact a record medium, such as paper 59 through an inked ribbon 58. The result of this is that the individual printing elements 12 are energized in a sinusoidal time pattern to cause selected styli 57 to be displaced toward the record medium 59 to effect printing of dot indicia at selected equally spaced column locations on said print medium.

Referring to FIGURE 4, there is shown graphically the manner in which the sync pulses are related to print head displacement. The sync generator 50 detects the zero crossing points of the sensor output velocity signal to provide the desired sync pulses at the maximum left and right hand excursions of the print head.

FIGURE 5 illustrates graphically in expanded form the relationship between equal dot column positions on the print medium 59 and the time of actuation of the printing styli 57. Generator 51, in one embodiment, comprises microprocessor 46, such as an Intel 8088, which responds to the sync pulses to address a lookup table to determine when an enable signal must be generated over lead 55 for application to the gating logic 52 such that printing will take place by displacements of the printing styli 57 under the control of printing coils 56. The displacements occur in a sinusoidal time pattern as shown by the abscissa of FIGURE 5 to cause selected printing styli, depending on the print information available from source 53, to be fired or displaced toward the record medium 59 to effect printing of indicia at selected equally spaced column locations on the print medium which is shown as the ordinate in FIGURE 5. The use of a microprocessor and a lookup table to obtain desired timing information, of course, is well known. The availability of print information from a source is also well known in the printing art as is the use of gates responsive to timing pulses and print information to obtain desired printing.

While this invention has been described with reference to particular embodiments and examples, in view of the above teachings, other modifications and variations will occur to those skilled in the art. Accordingly, it should be understood that the scope of the invention is defined by the following claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a matrix printer comprising a frame and having a print head mounted for reciprocating movement along a line of indicia to be printed on a printing medium, the improvement comprising:

first spring means for supporting the print head on the frame,

drive means for electromagnetically reciprocating the print head along the line,

second spring means for supporting said drive means on the frame,

the masses of the printhead and said drive means being dimensioned so that the combination of (1) the print head and first spring means and (2) said drive means and said second spring means forms a balanced spring/mass system having a natural resonant frequency of oscillation of sinusoidal motion along the path of the reciprocating movement of the print head array,

means for energizing said drive means with drive signals to cause said print head to move with a sinusoidal velocity pattern corresponding to said resonant frequency, said print head comprising print actuators and printing elements, and

means for selectively energizing said print actuators to cause selected printing elements to be displaced toward said printing medium to effect printing of indicia at equally spaced column locations in a sinusoidal time pattern to achieve an indicia print rate corresponding to said resonant frequency of oscillation.

2. The improvement of claim 1 wherein said drive means comprises a coil mechanically connected to said second spring means and a permanent magnet core fixed to said print head, said energizing means being electrically connected to said coil.

3. The improvement of claim 2 wherein said first and second spring means comprise leaf springs.

4. The improvement of claim 3 wherein the print head, said motor means and said first and second spring means are all disposed in a substantially horizontal plane.

5. The improvement of claim 3 further comprising sensing means for continuously sensing the movement of the printhead and producing a signal indicative of said movement and means responsive to said signal for controlling said energizing means to energize said motor means to maintain said sinusoidal motion.

6. A method of reciprocating a shuttle print head array along a line of print on a printing medium in a matrix printer, comprising:

mounting the print head array on springs,

providing a linear electric motor having a coil and having a permanent magnet core fixed to the print head array,

mounting the coil on springs,

making the mass of the coil equal to the mass of the print head array to form a balanced mass/spring system which has a natural resonant frequency of oscillation of sinusoidal motion along the path of reciprocation,

energizing the motor with sinusoidal alternating current having a frequency equal to said resonant frequency, and

choosing said resonant frequency to correspond to a desired print rate.

7. In a matrix printer comprising a frame and having a print head mounted for reciprocating movement along a line of indicia to be printed on a printing medium, the improvement comprising:

first spring means for supporting the print head on the frame,

drive means for electromagnetically reciprocating the print head along said line,

second spring means for supporting said drive means on the frame,

the masses of the print head and said drive means being dimensioned so that the combination of (1) the print head and first spring means and (2) said drive means and said second spring means forms a balanced spring/mass system having a natural resonant frequency of oscillation of sinusoidal motion along the path of the reciprocating movement of the print head,

means for energizing said drive means with drive signals to cause said print head to move with a sinusoidal velocity pattern corresponding to said resonant frequency, said print head comprising a plurality of print actuators and a plurality of associated printing elements, and

means for selectively energizing said print actuators in a sinusoidal time pattern to cause the associated selected printing elements to be displaced toward said printing medium to effect printing of indicia at selected equally spaced column locations on said print medium.

8. The improvement according to claim 7 wherein said drive means comprises a first member rigidly coupled to said second spring means and a second member rigidly coupled to said first spring means and said print head, means for energizing one of said members, the other one of said members responding to said last named energizing to cause reciprocating motion of said print head, and said first member dimensioned to operate as a counterweight to said print head during such reciprocating motion.

9. The improvement according to claim 8 wherein said first member comprises a coil mechanically connected to said second spring means, and said second member comprises a permanent magnet core fixed to said print head, said energizing means being electrically coupled to said coil.

10. The improvement of claim 9 wherein said first and second spring means comprise leaf springs.

11. In a matrix printer comprising a frame and having a print head mounted for reciprocating movement along a line of indicia to be printed on a print medium,

first spring means for supporting the print head on the frame,

drive means for electromagnetically reciprocating the print head along said line,

second spring means for supporting said drive means on the frame, means for minimizing the vibration forces on the frame caused by reciprocation of said print head comprising the masses of said print head and said drive means being dimensioned to form a counterbalanced spring/mass system having a natural resonant frequency of oscillation of sinusoidal motion along the path of the reciprocating movement of the print head,

means for energizing said drive means with drive signals to cause said print head to move with a sinusoidal velocity pattern corresponding to said resonant frequency, said print head comprising a plurality of equally spaced printing elements, and

means for selectively energizing said printing elements in a sinusoidal time pattern to cause selected printing elements to effect selective printing of indicia at equally spaced column locations on said print medium.

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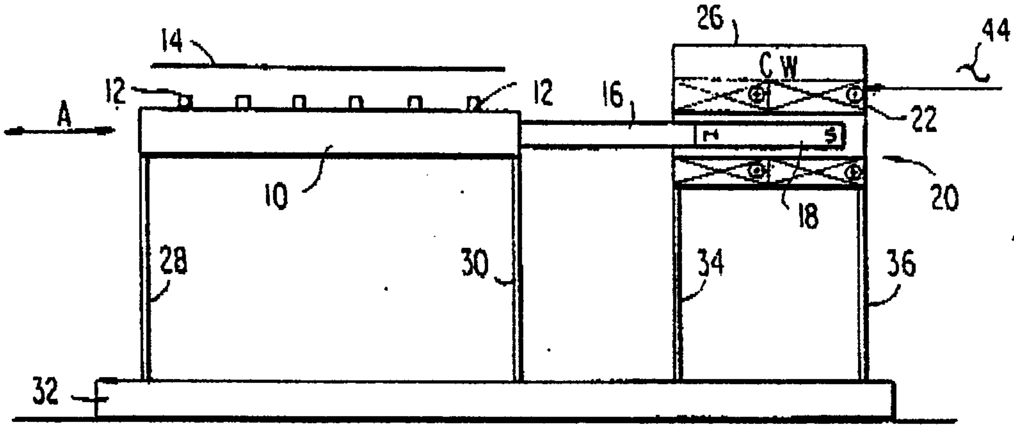
FIG.1



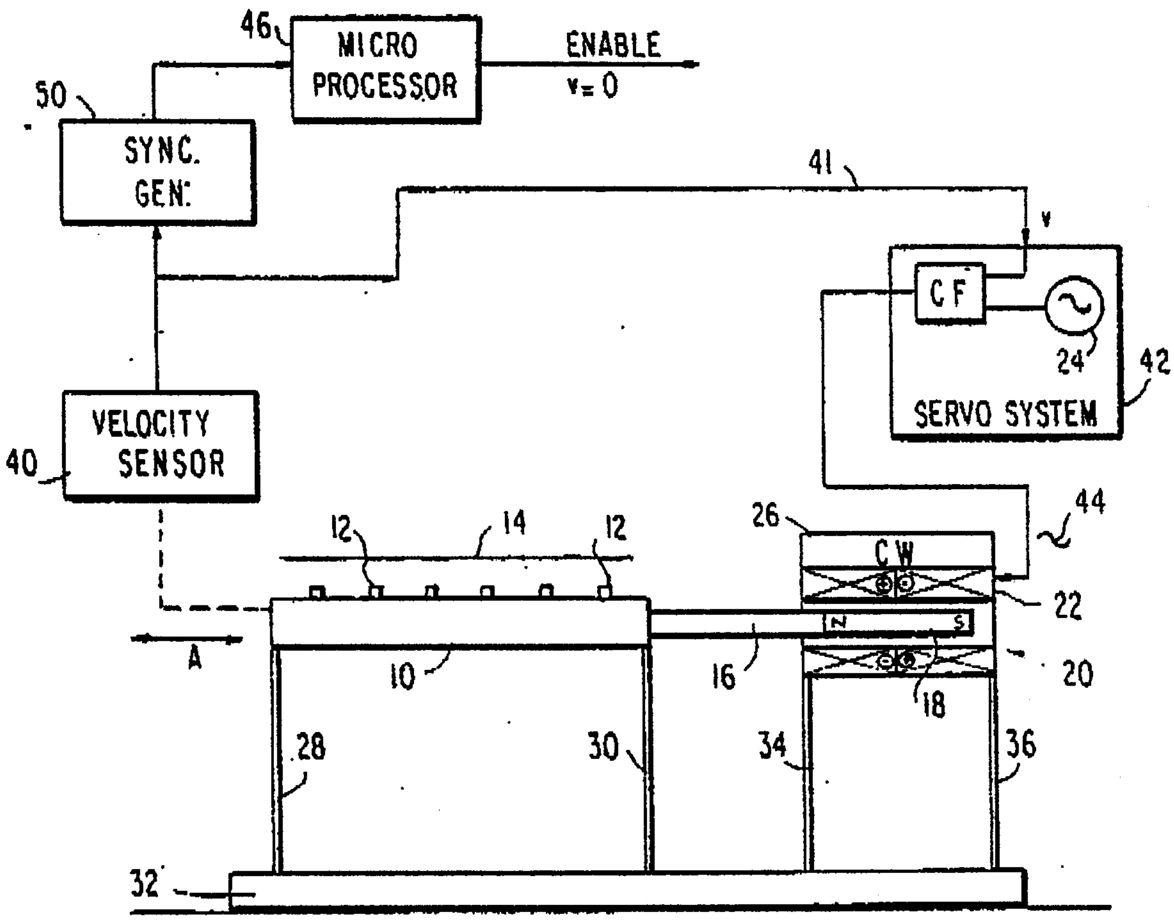


FIG.2

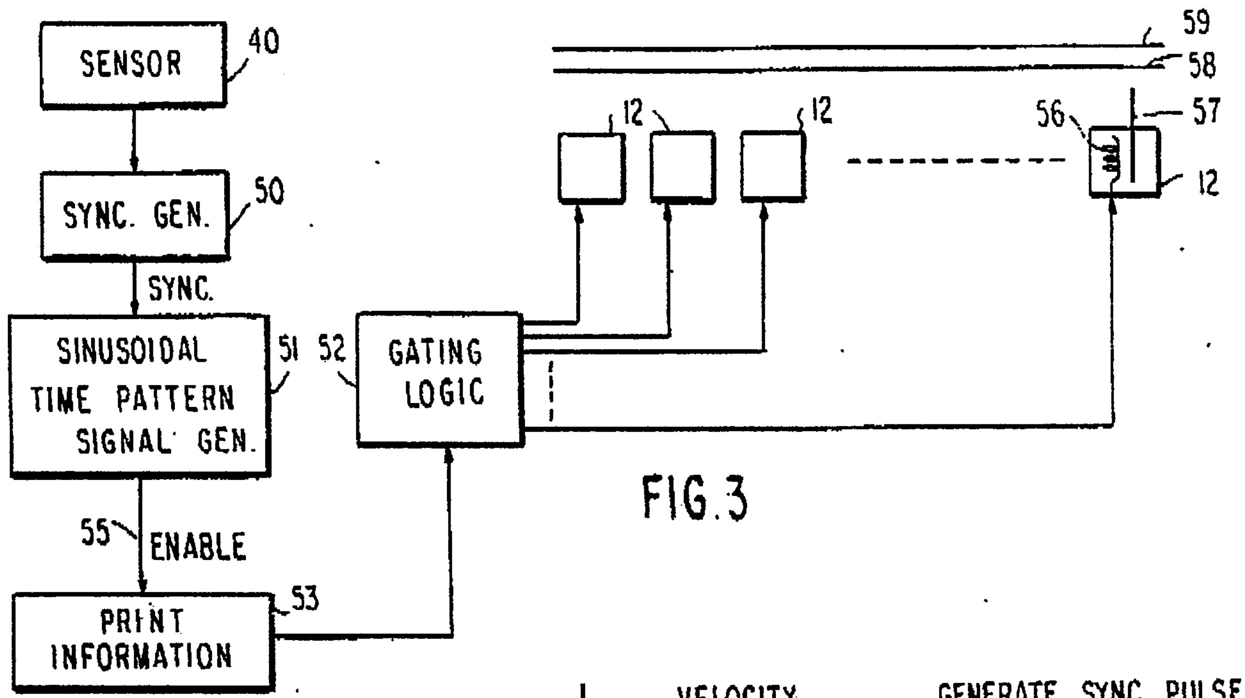


FIG.3

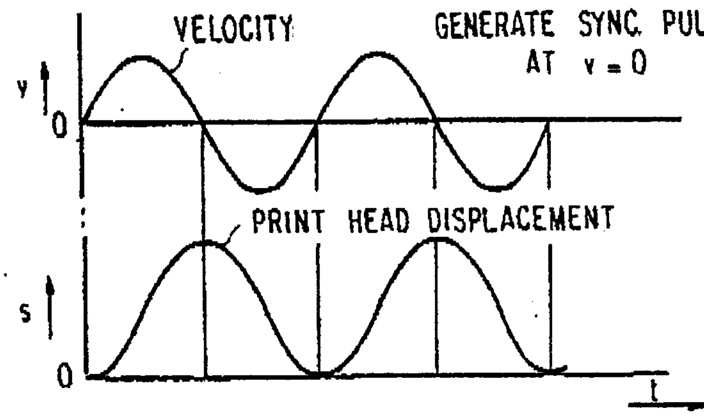


FIG.4

FIG.5