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Applicant: **Hewlett-Packard Company**
3000 Hanover Street
Palo Alto,
California 94304 (US)

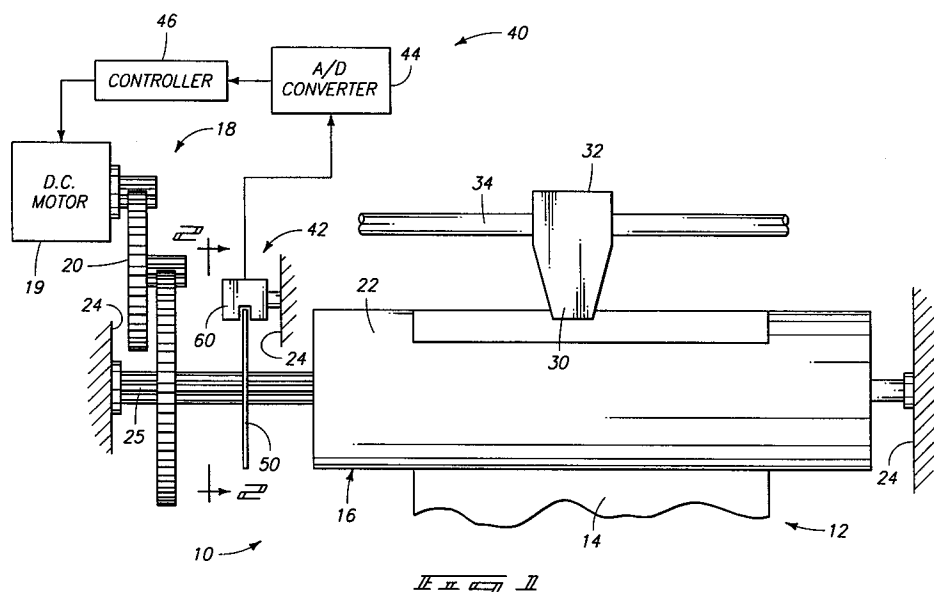
Inventor: **Rice, Huston W.**
6705 NE 126th Street
Vancouver, WA 98680 (US)
Inventor: **Beretta, Robert K.**
612 Cedar Street
Vancouver, WA 98661 (US)

Representative: **Colgan, Stephen James et al**
CARPMAELS & RANSFORD
43 Bloomsbury Square
London WC1A 2RA (GB)

Optical control system for media handling assemblies in printers.

A media motion controller for a printer uses a low cost, low resolution optical encoder (such as an LED encoder) which outputs an analog signal with a repeatable cycle indicative of media movement through the printer. An A/D converter is connected to the optical encoder to convert the analog signal into multiple discrete digital levels, where an increment of movement of the recording media is defined as

the movement during an interval between a selected discrete digital level in one cycle to the same selected discrete digital level in the next cycle. A controller is coupled to the A/D converter to receive the discrete digital levels and controllably move the media a selected number of movement increments as derived from recurrence of the selected discrete digital level during individual cycles.



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Technical Field

This invention relates to printers, and more particularly, to optical control systems for precision control of media motion.

Background of the Invention

Conventional printers have a media feed assembly which advances a recording media, such as paper, through the printer. The media feed assembly typically consists of friction rollers or a tractor feed mechanism and a motor coupled to rotate them.

The media feed assembly is synchronized with the printing operation. Upon completion of each line of text or graphics, the media feed assembly incrementally advances the recording media within the printer to the next line.

A problem of prior art printers concerns the accuracy in the stepped advancement of the recording media. This problem is particularly manifest in low cost printers which employ lower cost motors and gear arrangements that have less stringent tolerance requirements. Low cost motors have inherent inaccuracy by nature of the comparatively lower tolerance requirements. Imperfect gears also introduce paper displacement errors that vary as a function of gear position. The combined effect of low precision motors and gear arrangements results in errors in paper movement that undesirably degrade print quality. One common print quality problem is known as "horizontal banding" of the print image, where the displacement errors cause the paper to move a wrong amount between printed lines.

One prior art solution to this paper handling problem is simply to use higher precision motors and gears. Unfortunately, these components are expensive and impractical for use in low cost printers.

Another prior art solution is to utilize a sensor to monitor paper movement and feed back the motion information to control paper advancement. Optical sensors have been used for this task. There are two general categories of optical sensors: low cost, low precision optical sensors and high cost, high precision optical sensors. Low cost optical sensors have a drawback in that the resolution of such sensors may not be sufficiently precise for a given printer application. Low cost optical sensors have a typical resolution of no less than 0.001 inch. The more expensive optical sensors (such as encoders with extremely precise mounting tolerances, or sensors that employ lasers as the optical source) are too expensive for suitable application in low cost printers.

There are other types of sensors capable of monitoring paper movement, including highly precise magnetic field encoders, but these sensors are generally quite expensive and again not suitable for incorporation in low cost printers.

There is therefore a continuing need in the design of low cost printers to improve precision paper handling without using high priced components.

Disclosure of the Invention

This invention concerns a media motion apparatus for a printer which employs a low cost, low resolution optical sensor to monitor media motion and feed back information for precision media advancement control.

According to one aspect of this invention, a media motion controller includes a code wheel that rotates as the media is fed through the printer and an optical encoder adjacent to the code wheel to optically detect the rotation. The optical encoder outputs at least one analog signal with a repeatable cycle that is indicative of the moving code wheel.

The media motion controller also includes an A/D converter connected to the analog optical encoder to receive the analog signal and convert it into multiple discrete digital levels within the cycle. For control purposes, an increment of movement of the recording media through the printer is defined as the amount of movement during an interval between a selected discrete digital level in one cycle to the same selected discrete digital level in the next cycle. A controller is coupled to the A/D converter to receive the discrete digital levels from the A/D converter and controllably move the media a selected number of movement increments as derived from recurrence of the selected discrete digital level during individual cycles.

According to another aspect of this invention, the controller uses the remaining discrete digital levels to target the selected discrete digital level during a final increment of travel to precisely stop the media movement upon completion of the selected number of increments.

Brief Description of the Drawings

Preferred embodiments of the invention are described below with reference to the following accompanying drawings depicting examples embodying the best mode for practicing the invention.

Fig. 1 is a diagrammatic illustration of a media motion apparatus according to this invention configured using a drive roller as the media handling assembly.

Fig. 2 is an end view of the drive roller taken at line 2-2 in Fig. 1 and shows a code wheel of this

invention.

Fig. 3 is an enlarged view of the upper portion of the code wheel in Fig. 1, and shows the interaction of a two-channel optical encoder and the code wheel.

Fig. 4 demonstrates an analog output signal from the two-channel optical encoder of Fig. 3 in relation to detecting alternating demarcations and spaces on the code wheel.

Fig. 5 shows two approximately sinusoidal output signals A and B from the two-channel optical encoder of Fig. 3. Signals A and B are phase shifted relative to one another by 90°.

Detailed Description of the Preferred Embodiments

Fig. 1 shows a media motion apparatus 10 for a computer printer. Media motion apparatus 10 of this invention is particularly well suited for printers that move the recording media in a discontinuous series of steps, such as shuttle-type printers which advance the media a selected distance upon completion of each printing swath of the print head. Media motion apparatus 10 is therefore described in the context of an ink-jet printer. Aspects of this invention may also be used, however, in other types of printers, such as dot matrix and daisy wheel printers.

Media motion apparatus 10 includes a media handling assembly 12 which incrementally moves a recording media 14 through the printer. Media 14 may be a continuous form or individual sheet stock, and it can consist of paper, adhesive-backed labels, or other types of printable matter. Media handling assembly 12 preferably consists of a roller subassembly 16 which advances media 14 through frictional contact, and drive means 18 which powers roller subassembly 16. Drive means 18 comprises a DC motor 19 which changes speed and direction in relation to the level and plurality of DC voltage applied thereto and a gear arrangement 20 which mechanically couples DC motor 19 to roller subassembly 16. Alternatively, drive means 18 could comprise a stepper motor which changes speed and direction in response to intermittent pulses.

Roller subassembly 16 includes a primary drive roller 22 rotatably mounted to a printer frame 24. Drive roller 22 is rotated by drive means 18 to incrementally move recording media 14 through the printer. Drive roller 22 has a surface of effective friction to contact and move media 14. Roller subassembly 16 also has one or more secondary pinching rollers 26 (Fig. 2) adjacent to and engaging drive roller 22. Pinching rollers 26 are non-driven and rotate through engagement with primary roller 22. Pinching rollers 26 hold recording media 14 against drive roller 22 to facilitate movement of

the media through the printer and beneath the print head. It should be noted that this invention can be used in conjunction with other media handling assemblies, such as tractor feed systems.

A print head 30 is mounted adjacent to drive roller 22 to deposit printed images onto recording media 14. In the context of the ink-jet printer being described herein, print head 30 is provided on a reciprocating carriage 32 that is slidably mounted on a fixed, elongated rod 34 to move the print head bi-directionally across platen 36 (Fig. 2). A carriage drive subassembly (not shown) powers carriage 32 and print head 30 back and forth along rod 34.

Media motion apparatus 10 further includes a media motion controller 40 for controlling movement of recording media 14 through the printer. Media motion controller 40 includes an analog optical encoder system 42, an A/D (analog-to-digital) converter 44, and a controller 46.

Optical encoder system 42 is provided in detection proximity to media handling assembly 12 to detect its movement and hence, the movement of recording media 14. As shown in Figs. 1 and 2, optical encoder system 42 preferably comprises a code template in the form of a circular code disk or wheel 50 mounted adjacent to one end of primary roller 22. Code wheel 50 rotates as roller 22 is rotated. Code wheel 50 is illustrated on the roller end that is next to gear arrangement 20 to reduce any torsional effect of shaft 25 during rotation, although other locations are also suitable. Code wheel 50 has a preferred diameter that is approximately equal to the diameter of the surface of roller 22, although other diameters are possible. An example diameter of code wheel 50 is two inches.

Code wheel 50 has multiple equally spaced demarcations 52 and spaces 54 between adjacent demarcations provided at the circumferential edge. Demarcations 52 are preferably in the form dark colored radially oriented stripes. An example spacing between the centers of adjacent stripes 52 is 1/200 inch (0.005 inch).

Code wheel 50 is preferably formed of a light-transmissive material, such as Mylar™, and stripes 52 are formed of a non-transmissive ink or dye that are printed or otherwise deposited thereon. In this manner, stripes 52 prevent passage of light therethrough and spaces 54 permit passage of light therethrough. It is noted that other types of code templates having different shapes (e.g., linear code strips) or demarcations (e.g., reflective dye or holes) can be used.

Optical encoder system 42 further includes an optical encoder 60 adjacent to rotary code wheel 50 to optically detect and differentiate between the demarcations 52 and spaces 54 on the code wheel. Optical encoder 60 is mounted in a stationary manner to frame 24 so that code wheel 50 moves past

optical encoder 60.

As shown in Fig. 3, analog optical encoder 60 is preferably a two-channel encoder. Optical encoder 60 includes a light source 62 oriented to emit a light beam through the radially projecting edge of the transmissive code wheel 50 and two light sensitive detectors 64a and 64b aligned to detect light passing through circular code wheel 50. Light source 62 is preferably embodied as an LED (light emitting diode) source, although other types are possible. Examples of light sensitive detectors 64 include photodetectors, charged coupled devices, photodiodes, and phototransistors. It is noted that optical encoder 60 may alternatively be configured as a reflective encoder device wherein the light source 62 and light sensitive detectors 64a and 64b are positioned on the same side of the code wheel. In this alternative embodiment, the demarcations on the code wheel reflect the light beam from the light source back to the light sensitive detectors.

When drive roller 22 is rotated by drive means 18 to advance the media, rotary code wheel 50 is likewise rotated causing an alternating pattern of stripes and spaces to pass through optical encoder 60. In response, optical encoder 60 outputs at least one, and preferably two, analog signals A and B indicative of the roller rotation. With the preferred diameter of the code wheel being equal to that of roller 22, the patterned edge of code wheel 50 passes between the LED and light sensitive detector of encoder 60 at about the same radius as the radius of the roller surface, thereby providing a corresponding relationship between the encoder output and the media movement.

Fig. 4 illustrates one analog signal output by encoder 60 in relation to the stripes and spaces on the code wheel. The analog signal has a repeatable cycle including a first amplitude 70 during detection of a stripe 52 to a second amplitude 72 during detection of a space 54. The demarcations are sized and spaced such that width W_D of demarcation 52 and width W_S of space 54 are equal. This permits generation of a more continuous analog output signal. The analog signal approximates a sinusoidal wave, although it is imperfect due to imperfections in the encoder and code wheel. If desired, the signal can also be inverted so that the high amplitude peak corresponds to a space 54 and the low amplitude valley corresponds to a demarcation 52.

In comparison to optical encoder 60, prior art low cost optical sensors are designed to output a digital signal which switches between two states: on (or high) and off (or low). Such optical sensors employ an internal Schmitt trigger connected to the encoder analog output to transition between on and off states in relation to the analog output rising

above and falling below a threshold level. The optical encoder of this invention does not use a Schmitt trigger, but instead outputs the analog signal.

Fig. 5 illustrates the two analog outputs A and B of two-channel optical encoder 60. The two-channel optical encoder permits detection of both position of primary roller 22 and direction of its rotation. Direction is determined by the phase shift between the two signals A and B. For one rotational direction of roller 22, output signal B lags output signal A by 90° ; whereas for the opposite rotational direction, output signal B leads output signal A by 90° .

Returning to Fig. 1, the two analog output signals A and B from optical encoder 60 are input into A/D converter 44. A/D converter 44 samples the analog signals and converts each signal into multiple discrete digital levels within a given cycle. The A/D converter permits high resolution of the analog signal, particularly within the transition portions of the sinusoidal waves, as indicated in Fig. 5 as the "high resolution region".

An n-bit A/D converter provides 2^n discrete digital levels between the upper and lower amplitudes of the analog signals. This invention preferably uses low cost, low resolution optical encoders of the type which detect movement of not less than 0.001 inch. For an n-bit A/D converter, media motion apparatus 10 that is utilizing such low resolution optical encoders is capable of detecting movement to approximately $0.001/2^n$ inch (or $0.05/2^n$ degree for rotational movement) which significantly improves controller resolution and thus allows for more precise handling of the media.

Consider the following example with reference to Fig. 5. Suppose that one cycle of analog signal A from point C to point D is representative of roller movement of $1/200$ inch (0.005 inch). This corresponds to the center-to-center spacing of demarcations 52 described above. Transition region T of one portion of analog signal A between the amplitude peaks represents a roller movement of approximately $1/1000$ inch (0.001 inch). An 8-bit A/D converter can divide this region T between amplitude peaks into nearly 2^8 or 256 discrete digital levels, thereby providing a resolution of analog signal A of nearly $0.001/256$ inch, or 3.9×10^{-6} inch in this region. It is also possible to fine tune the A/D converter to operate only within the region T such that all 256 discrete digital levels occur in region T. This significantly enhances resolution, and affords a considerable advantage in comparison to the single data point provided by the prior art sensors which employ the Schmitt trigger or similar circuitry.

The multiple discrete digital levels output by A/D converter 44 allow the media motion controller

to stop at a desired place on the analog curve with a very high degree of precision. With reference to Fig. 5, for example, media motion controller 40 can identify one selected discrete digital level (for example, point C) in Cycle One and the same selected discrete digital level (for example, point D) in the subsequent Cycle Two with great accuracy. This is particularly useful in media motion which can be characterized as multiple discrete increments of movement, where each increment of movement is equal to the roller movement during the interval of one complete cycle of the analog signal output from optical encoder 60 (i.e., from one discrete digital level, point C, in one cycle to the same discrete digital level in the next cycle, point D). Again, this increment of movement corresponds to the rotation amount of roller 22 from one stripe (or space) to the next.

Although each analog signal output by optical encoder 60 is not a perfect sine wave, there exists an inherent cycle accuracy from any given point on one cycle to the same point on the next cycle. Indeed, the accuracy is limited only by the accuracy of the code wheel, which can be highly precise.

Controller 46 receives the different discrete digital levels from A/D converter 44, and provides feed back control information to DC motor 18 to provide precision position control of drive roller 22. In this manner, optical encoder system 42, A/D converter 44, and controller 46 provide feed back means for precision motion control of the recording media through the printer. Controller 46 moves media 14 a selected number of movement increments as derived from recurrence of the selected discrete digital level during individual cycles (i.e., points C, D, etc). The ability to segment the analog signal into multiple discrete digital levels within each cycle allows the controller to zero-in and target the specific spot along the analog curve during each cycle.

As an example of how media motion apparatus 10 operates, suppose that the printer is set in the text mode to print eight lines per inch. To move from one line to the next, media handling assembly 12 increments the media one-eighth inch, or 0.125 inch. For the example code wheel having a center-to-center spacing of 1/200 inch, this step movement equates to twenty-five increments (i.e., $0.125"/0.005" = 25$). Media motion controller 40 instructs drive means 18 to rotate roller 22 twenty-five stripes on rotary code wheel 50 as monitored by recurrence of a selected digital output level (i.e., points C, D, etc.) in each cycle. Controller 46 stops media handling assembly 12 upon completion of the 25th increment as indicated by reaching the selected discrete digital level in the final cycle.

Due to the inherent cycle accuracy of the digitized signal, the media motion controller 40 can move the media precisely twenty-five increments. Another advantageous aspect of this invention is that the controller can use the remaining discrete digital levels within each cycle other than the chosen discrete digital level (i.e., points C, D) to target the selected digital level in the final 25th increment. This allows controller 46 to slow media handling assembly 12 during the 25th increment, and stop it precisely upon arriving at the selected discrete digital level.

The media motion controller of this invention is therefore advantageous over prior art controllers in that it uses low cost, low resolution LED-source optical encoders and A/D converters to achieve very high precision for step movements of distances that are integer numbers of the stripes on the code wheel. The media motion controller of this invention allows precision control of the media motion to substantially reduce or eliminate such problems as "horizontal banding" without resorting to the use of expensive encoders, motors, or gear couplings.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

Claims

1. A media motion apparatus for a printer comprising:
 - a media handling assembly (12) to incrementally move the recording media (14) through the printer;
 - a code template (50) having multiple equally spaced demarcations (52) and spaces (54) between adjacent demarcations;
 - an analog optical encoder (60) adjacent to the code template (50) to optically detect and differentiate between the demarcations (52) and spaces (54);
 - one of the code template (50) or optical encoder (60) operably mounted to move as the media handling assembly (12) moves the recording media (14) through the printer, the optical encoder (60) detecting movement relative to the code template (50) that is indicative of movement of the recording media (14) through the printer, the optical encoder (60)

outputting an analog signal representative of the movement which has a repeatable cycle including a first amplitude during detection of a demarcation and a second amplitude during detection of a space;

an A/D converter (44) connected to the optical encoder (60) to receive the analog signal, the A/D converter (44) sampling the analog signal to convert the analog signal into multiple discrete digital levels within the cycle;

movement of the recording media by the media handling system during an interval between a selected discrete digital level in one cycle to the same selected discrete digital level in the next cycle defining an increment of movement; and

a controller (46) coupled to the A/D converter (44) and to the media handling assembly (12), the controller (46) receiving the discrete digital levels from the A/D converter (44) and controlling the media handling assembly (12) to move the recording media (14) a selected number of movement increments as derived from recurrence of the selected discrete digital level during individual cycles.

2. A media motion apparatus according to claim 1 wherein the controller (46) controls the media handling assembly (12) to stop moving the recording media (14) upon completion of the selected number of increments where a final increment is ended by the selected discrete digital level, the controller (46) using remaining discrete digital levels to target the selected discrete digital level in the final increment.

3. A media motion apparatus according to claim 1 wherein:

the analog optical encoder (60) detects movement of not less than 0.001 inch;

the A/D converter (44) comprises an n-bit A/D converter; and

the media motion apparatus is capable of detecting movement to approximately $0.001/2^n$ inch.

4. A media motion apparatus according to claim 1 wherein:

the media handling assembly (12) includes a roller (22) which rotates to move the recording media (14) through the printer; and

the code template (50) comprises a rotary code wheel mounted to the roller (22) to rotate as the roller is rotated, the rotary code wheel having multiple equally spaced radially oriented stripes and spaces between adjacent stripes; and

the optical encoder (60) is mounted adja-

cent to the code wheel (50) to optically detect and differentiate between the radial stripes and spaces.

5. A media motion apparatus according to claim 4 wherein the rotary code wheel is transmissive where the stripes prevent passage of light therethrough and the spaces therebetween permit passage of light therethrough.

6. A media motion apparatus according to claim 1 wherein:

the analog optical encoder (60) is a two-channel analog optical encoder which outputs two analog signals A and B, each of the analog signals A and B having a repeatable cycle; and

the A/D converter (44) converts each of the analog signals A and B into multiple discrete digital levels within respective cycles.

7. A media motion apparatus for a printer comprising:

a frame (24);

a roller subassembly (16) having at least one roller (22) rotatably mounted to the frame (24);

drive means (18) for rotating the roller (22) within the roller subassembly (16) to incrementally move a recording media (14) through the printer;

a rotary code wheel (50) mounted to the roller subassembly (16) to rotate as the roller (22) is rotated, the rotary code wheel (50) having multiple equally spaced demarcations (52) and spaces (54) between adjacent demarcations;

an optical encoder (60) mounted to the frame (24) adjacent to the code wheel (50) to optically detect and differentiate between the demarcations (52) and spaces (54), the optical encoder (60) outputting an analog signal indicative of the roller rotation, the analog signal having a repeatable cycle including a first amplitude during detection of a demarcation and a second amplitude during detection of a space;

an A/D converter (44) connected to the optical encoder (60) to receive the analog signal, the A/D converter (44) sampling the analog signal to convert the analog signal into multiple discrete digital levels within the cycle;

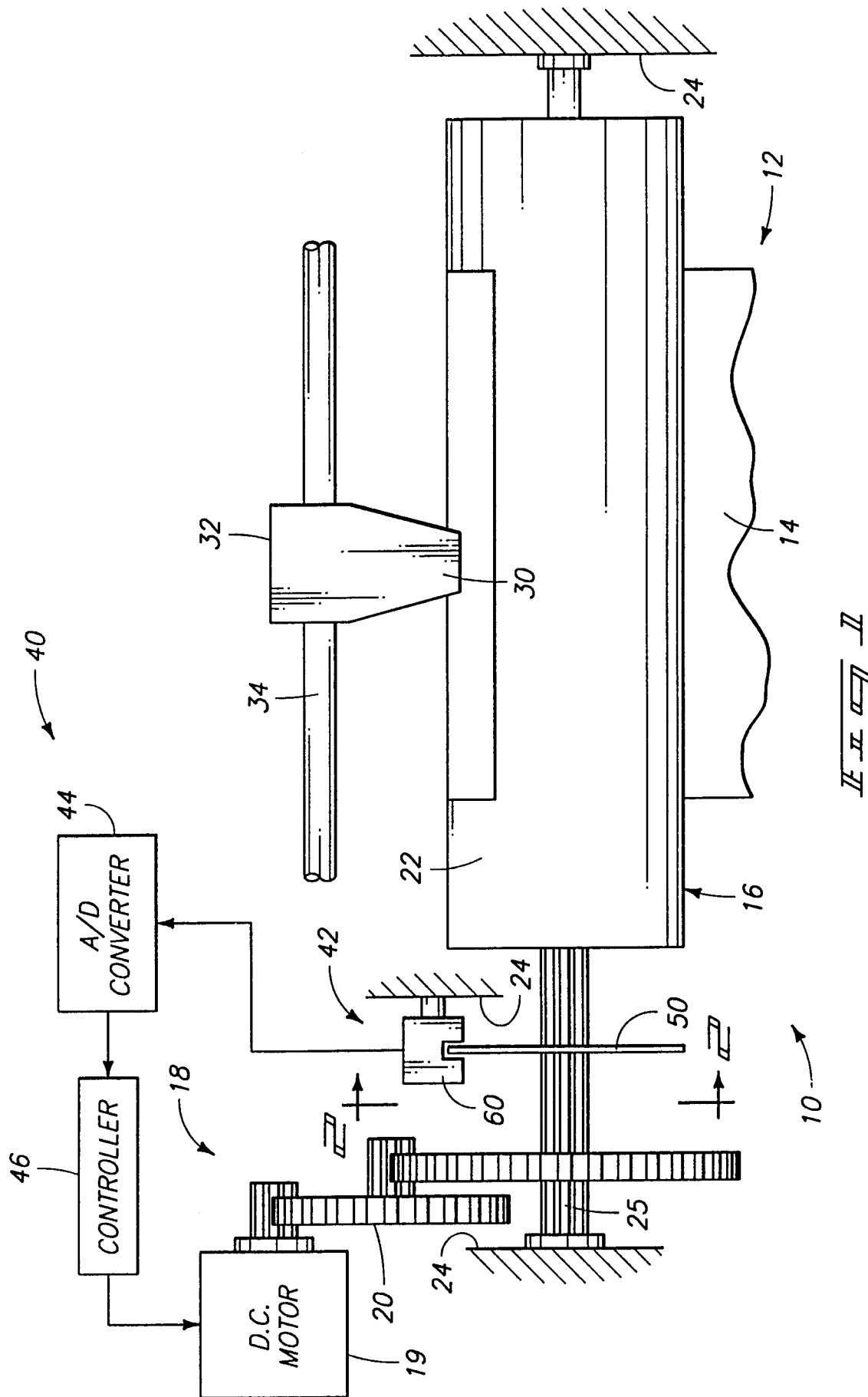
rotation of the roller (22) during an interval between a selected discrete digital level in one cycle to the same selected discrete digital level in the next cycle defining an increment of rotation of the roller; and

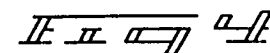
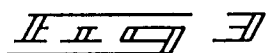
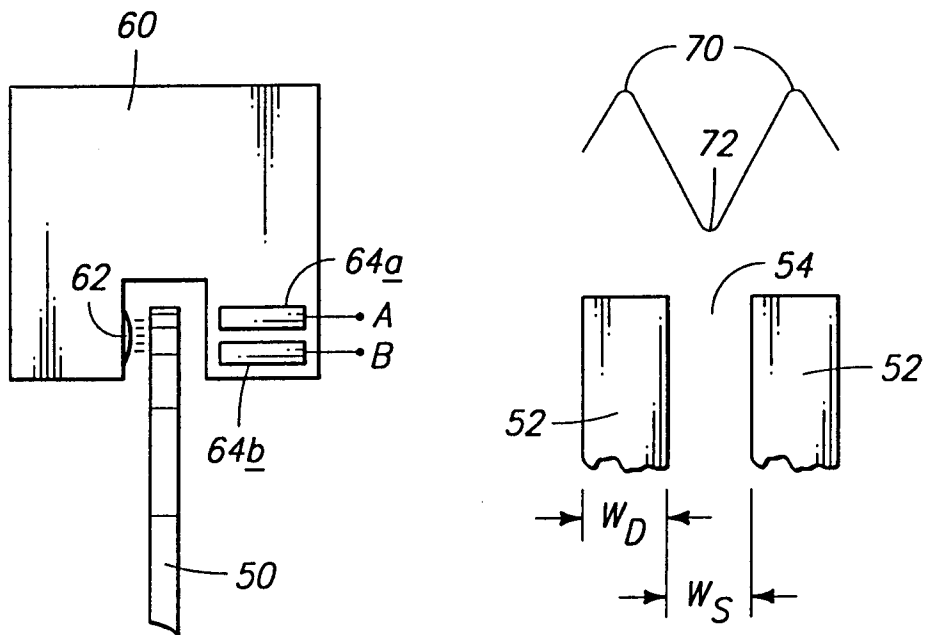
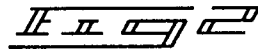
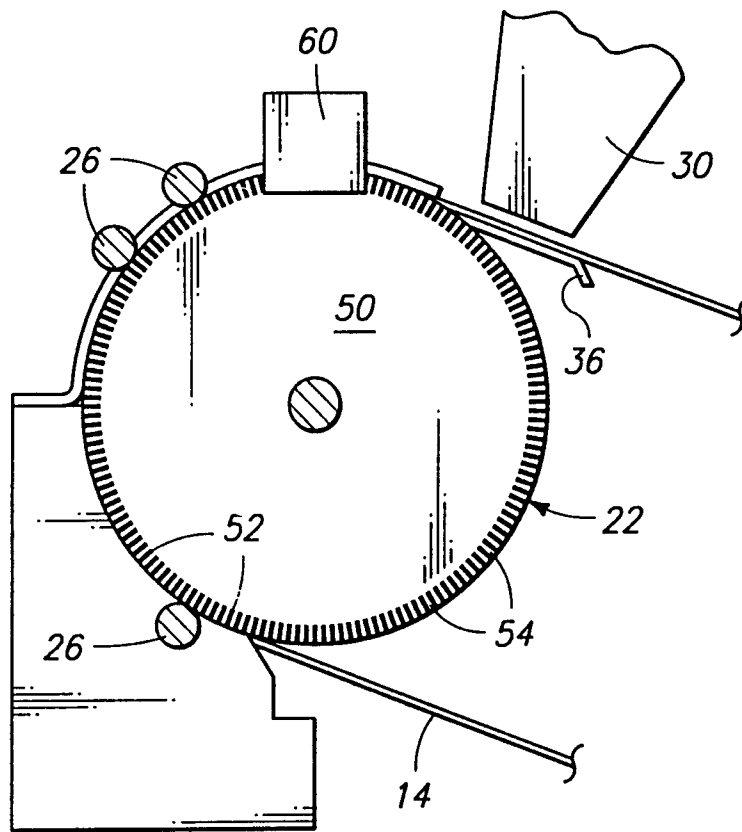
a controller (46) coupled to the A/D converter (44) and to the roller subassembly (16),

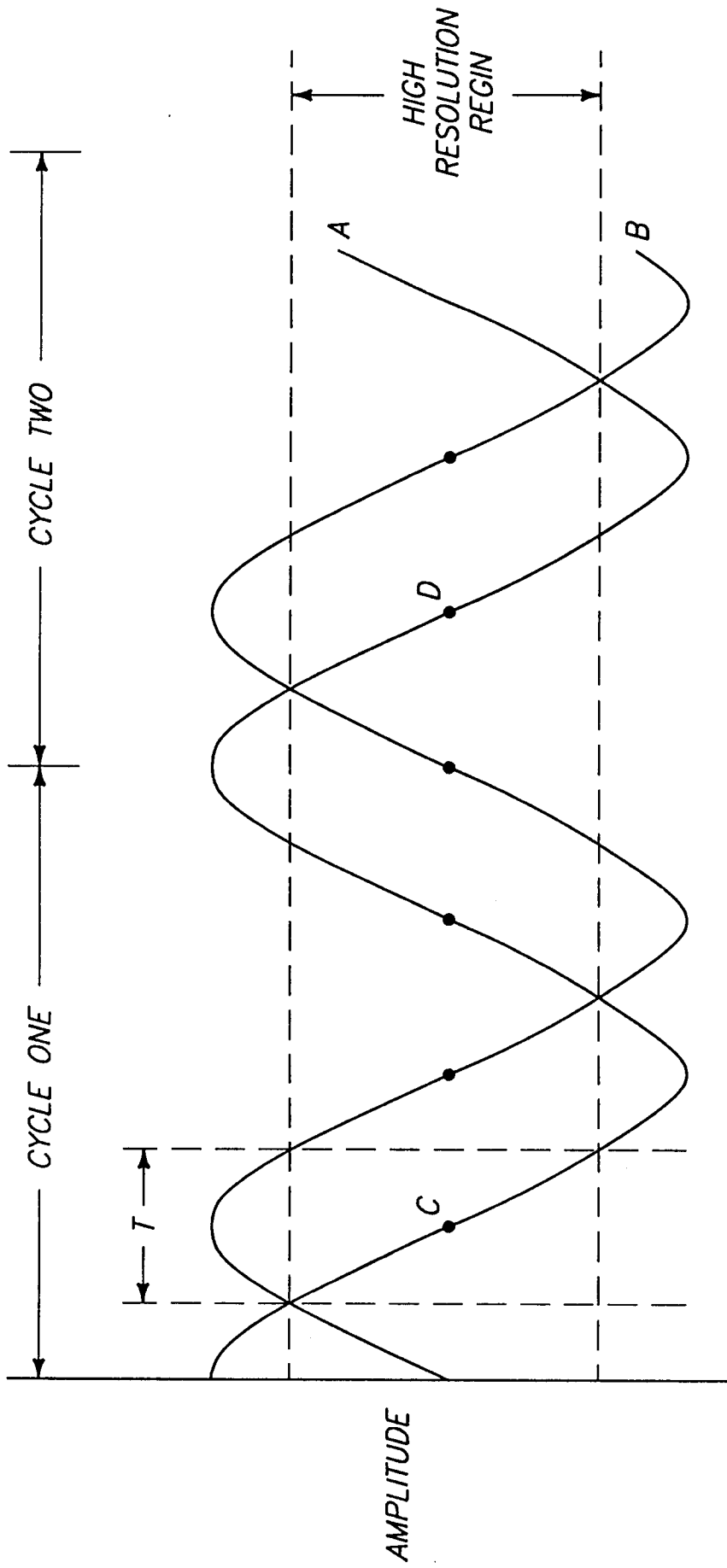
the controller (46) receiving the discrete digital levels from the A/D converter (44) and controlling the roller subassembly (16) to rotate the roller (22) a selected number of increments as derived from recurrence of the selected discrete digital level during individual cycles.

digital levels.

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 8. A media motion apparatus according to claim 7 wherein the code wheel (50) is transmissive where the demarcations prevent passage of light therethrough and the spaces therebetween permit passage of light therethrough. 10
 9. A media motion apparatus according to claim 7 wherein: 15
 - the optical encoder (60) detects movement of not less than 0.05° ;
 - the A/D converter (44) comprises an n-bit A/D converter; and
 - the media motion apparatus is capable of detecting movement to approximately $0.05/2^n$ degree. 20
 10. A media motion controller for controlling movement of a recording media through a printer, the motion controller comprising: 25
 - a code template (50) having multiple equally spaced demarcations (52) and spaces (54) between adjacent demarcations;
 - an optical encoder (60) adjacent to the code template (50) to optically detect and differentiate between the demarcations and spaces on the code template; 30
 - at least one of the optical encoder (60) or the code template (50) being moved relative to the other as the recording media (14) is moved through the printer, the optical encoder (60) detecting the relative movement by differentiating between the alternating demarcations (52) and spaces (54) on the code template during the movement, the optical encoder (60) outputting at least one analog signal indicative of the movement having a first amplitude during detection of a demarcation and a second amplitude during detection of a space, the analog signal having a repeatable cycle; 40
 - an A/D converter (44) connected to the analog optical encoder (60) to receive the analog signal, the A/D converter (44) sampling the analog signal to convert the analog signal into multiple discrete digital levels within the cycle; and 45
 - a controller (46) coupled to the A/D converter (44), the controller (46) receiving the discrete digital levels from the A/D converter (44) and controlling movement of the at least one optical encoder (60) or code template (50) relative to the other according to the discrete 55







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