Dec. 22, 1970 M. CAMRAS 3,550,149

MAGNETIC IMAGE PRINTING SYSTEM

Filed April 6, 1967 2 Sheets-Sheet 1

Fig-1

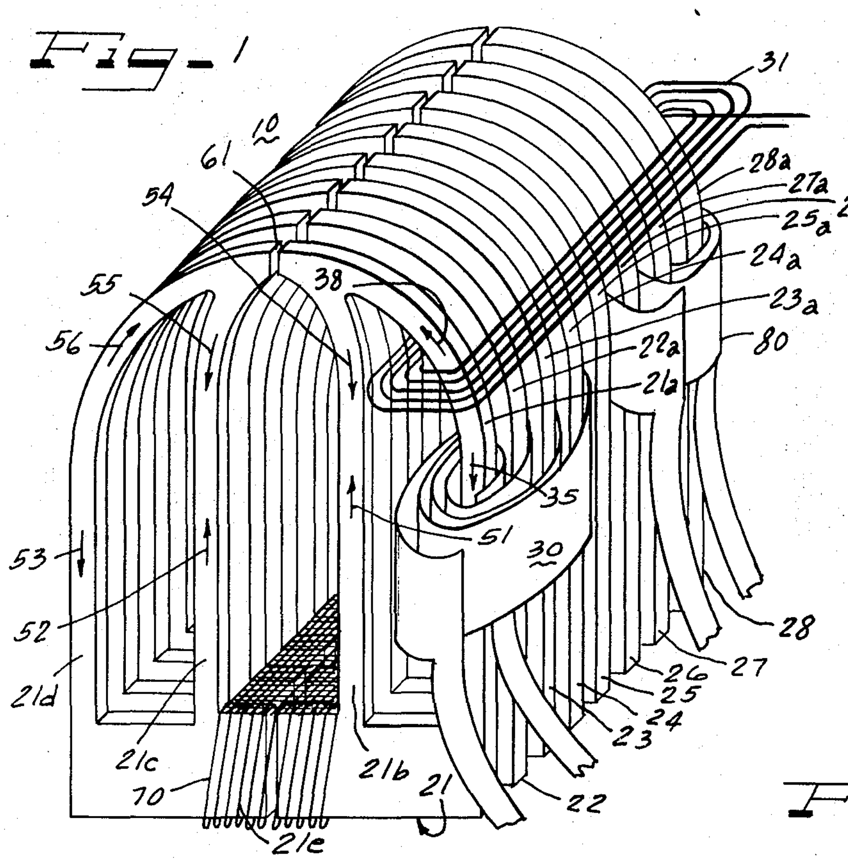
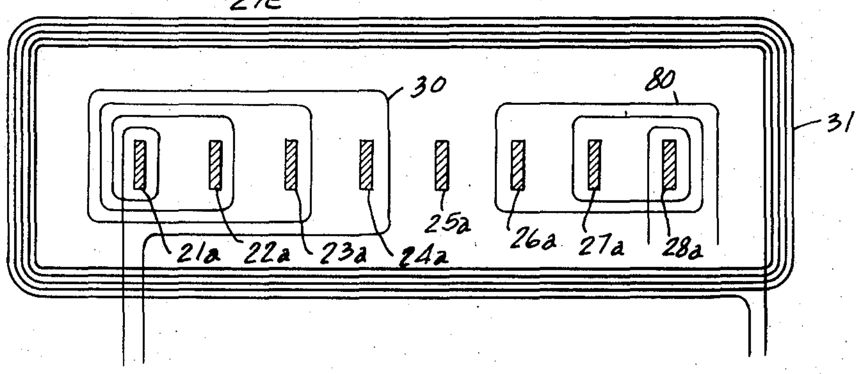


Fig-2



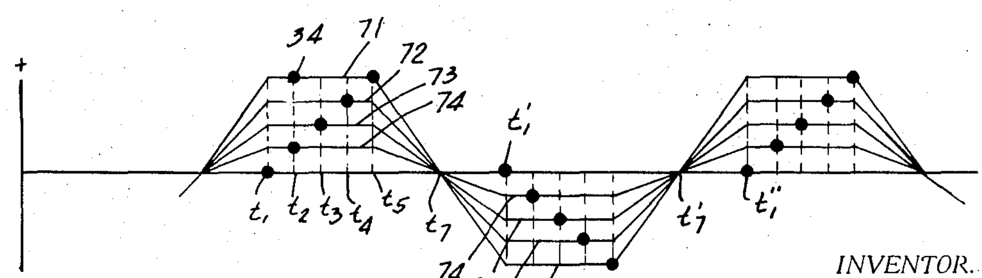


Fig-3A

INVENTOR.
MARVIN CAMRAS

BY Hill, Sherman, Meroni, Gross & Simpson ATTORNEYS

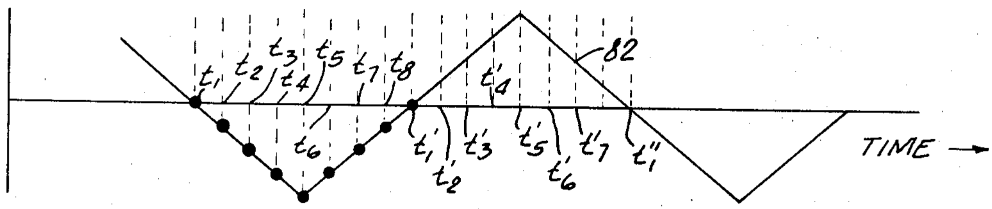
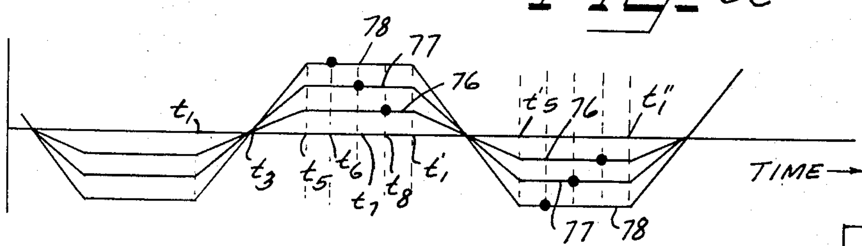


Fig. 3B

Fig. 3C



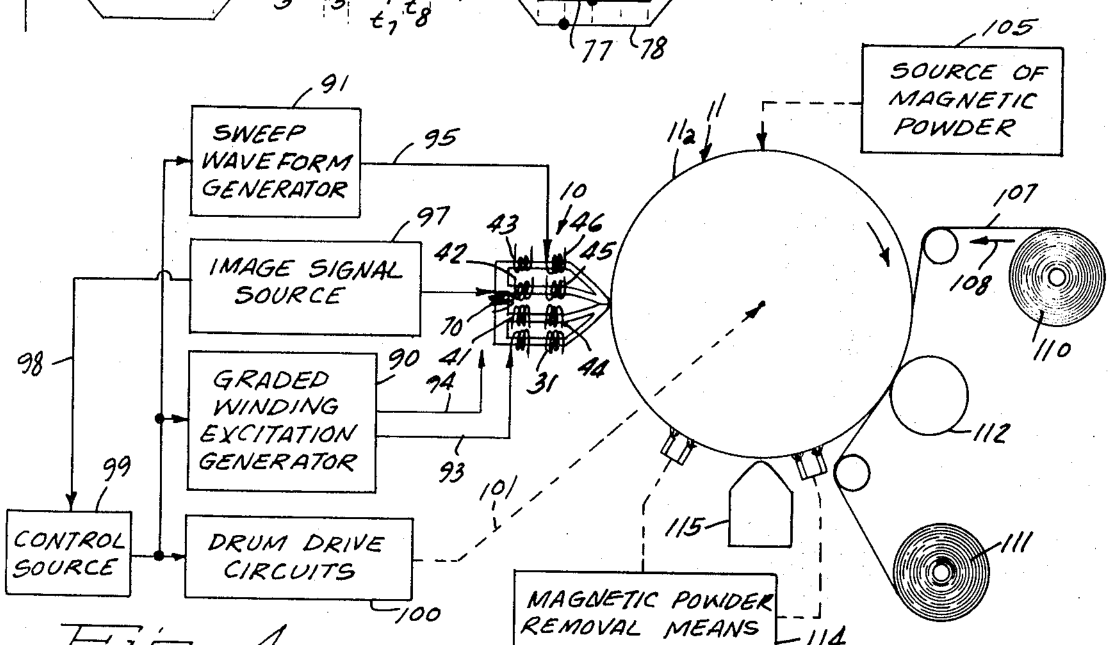


Fig. 4

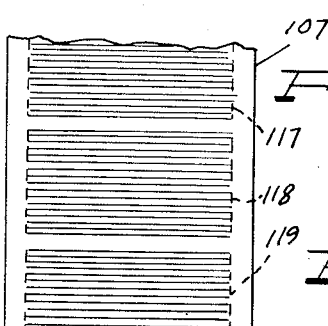


Fig. 5

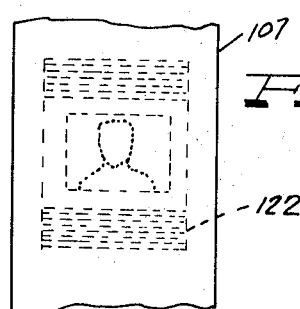
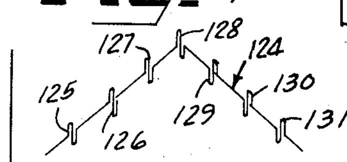


Fig. 6

Fig. 7



INVENTOR.
MARVIN CAMRAS

BY Hill, Sherman, Meroni, Gross & Simpson ATTORNEYS

3,550,149

MAGNETIC IMAGE PRINTING SYSTEM

Marvin Camras, Glencoe, Ill., assignor to IIT Research Institute, Chicago, Ill., a corporation of Illinois

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The portion of the term of the patent subsequent to May 7, 1985, has been disclaimed
Int. Cl. G01d *15/12;* G11b *5/20;* H04p *1/28*
U.S. Cl. 346—74 4 Claims

ABSTRACT OF THE DISCLOSURE

In the illustrated embodiment, core units are sequentially switched by applying first magnetomotive forces of alternating polarity and of generally rectangular waveform and second magnetomotive forces of alternating polarity and of substantially symmetrical generally triangular waveform to saturable magnetic material of the respective core units, and coordinating the frequencies, phases and amplitudes of the magnetomotive forces to provide substantially uniform time intervals between activation of the successive core units, particularly for the purpose of producing a magnetic image on a magnetizable record medium which may then be utilized to produce multiple "hard" copies of the recorded image. A special excitation waveform is also shown for precise timing of the switching of the individual core units.

BACKGROUND OF THE INVENTION

In the computer field, for example, an important problem is to provide output from the computer in the most usable and convenient form. In this case, one or multiple hard copies of such material should be available. It is here proposed that a series of magnetic head units record successive elements of an image on a magnetizable medium with linear timing of the activation of the head units to provide undistorted image print out. Where print out is to take place at a multiplicity of stations remote from a central computer, economy and simplicity of the image generating system is of the utmost importance. Accordingly, a rugged and reliable multichannel magnetic recording head of the stationary type represents an ideal component for such a system. Such a head requires a minimum of maintenance and its operation is reliable under varying temperature, humidity and other environmental conditions.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved image printing system and method having a minimum of moving parts and a maximum simplicity.

Another object of the invention is to provide a simplified core switching system for sequentially activating a series of magnetic core units.

A further object of the invention is to provide an improved system and method for magnetic recording utilizing a stationary multichannel magnetic recording head wherein the head units are sequentially activated at substantially uniform time intervals.

Still another object of the invention is to provide a core switching system utilizing linearly graded windings and yet which enables a uniform cycling of the series of cores over a complete cycle of the excitation waveforms.

Another and further object is to provide a core switching system and method with switching of each core at a precisely determined instant of time.

In my prior application Ser. No. 515,507 filed Oct. 13, 1965 now U.S. Pat. No. 3,488,454 issued Jan. 6, 1970, and in the earlier related applications now U.S. Pats.

No. 3,382,325 and 3,382,326, both issued May 7, 1968, I have shown embodiments for achieving a linear switching interval between successive cores with the use of a linearly graded winding; however, the excitation waveform for the sweep winding in such embodiments has required an abrupt return from a maximum value to a zero value in each half cycle. Further the switching interval is distorted in each of the abrupt return portions so that there is not a uniform time interval between activation of each of the cores of the series. The embodiment specifically illustrated in the drawings herein overcomes this problem by utilizing a generally triangular substantially symmetrical waveform for the excitation current supplied to the sweep winding as will be more fully understood from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic perspective view illustrating the construction of a magnetic transducer head in accordance with the present invention;

FIG. 2 is a diagrammatic illustration of the arrangement of the excitation windings for two groups of head units of the type shown in FIG. 1;

FIG. 3A is a waveform diagram showing the respective magnetomotive forces supplied by the graded winding to the respective head units of one group in FIG. 2;

FIG. 3B is a waveform diagram on the same time scale as FIG. 3A and showing the magnetomotive force applied to each of the head units of FIG. 2 by means of the sweep winding;

FIG. 3C is a waveform diagram similar to that of FIG. 3A but showing the magnetomotive forces applied to respective head units of the second group in FIG. 2;

FIG. 4 is a diagrammatic illustration of an image printing system utilizing a head assembly in accordance with the preceding figures of drawing;

FIG. 5 is a diagrammatic illustration showing the printed output from the system of FIG. 4 under a first set of operated conditions;

FIG. 6 is a diagrammatic view similar to FIG. 5 but showing the printed output from the system of FIG. 4 under a second set of operating conditions; and

FIG. 7 shows a special excitation waveform for use in place of the waveform of FIG. 3B for precise timing of the switching of individual core units in a core switching system and method such as illustrated in the preceding figures.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a head assembly **10** for cooperation with respective channels of a magnetic record medium such as the magnetizable surface **11***a* of a drum **11** shown in FIG. 4. The head assembly **10** is made up of a series of head units including for purposes of diagrammatic illustration a first group of head units **21–24** and a second group of head units **25–28**. Each of the head units comprises four legs of saturable magnetic material such as the legs **21***a*–**21***d* of the head unit **21**. Legs **21***a*–**28***a* of the respective head units **21–28** are indicated in FIG. 1 and are shown in cross section in FIG. 2. The respective aligned legs such as **21***a*–**28***a* have excitation windings thereon such as graded winding **30** and sweep winding **31** indicated in FIG. 1. The graded winding **30** is preferably of a ribbon configuration and is wound so as to link the legs **21***a*–**24***a* with successively fewer numbers of turns as is best seen in FIG. 2. Sweep winding **31** links all of the legs **21***a*–**28***a* with the same number of turns. At a given instant of time such as time t_2 represented in FIG. 3A, the graded winding **30** may receive current in a direction to establish a magnetomotive force such as represented by point **34** in FIG. 3A for core **21** and this magnetomotive force may be represented by arrow **35** in FIG. 1. At the same instant of time the sweep winding **31** may establish a magnetomotive force as represented by point **37** in FIG. 3B and as represented by arrow **38** in FIG. 1 opposing the magnetomotive force exerted on leg **21**a by the graded winding **30**. At the instant of time t_2, the magnetomotive force exerted by the winding **30** greatly exceeds that exerted by the winding **31**, so that legs **21**a and **21**b will be saturated in the clockwise direction as viewed in FIG. 1. As indicated diagrammatically in FIG. 4, legs **21**b, **21**c and **21**d may be provided with graded windings **41–43** similar to the graded winding **31** and may be provided with sweep windings **44–46** similar to the sweep winding **31**. At the instant of time t_2, windings **41–43** may exert magnetomotive forces in directions as represented by arrows **51–53** and windings **44–46** may exert magnetomotive forces as represented by arrows **54–56** in FIG. 1. The windings **30** and **41–43** may be connected in series and the windings **31** and **44–46** may be connected in series so that the magnetomotive force variations applied to each of the legs **21**a–**21**d may be essentially as represented in FIGS. 3A and 3B, but with the relative polarities as represented by the arrows in FIG. 1. Thus at the instant of time t_2, the magnetomotive forces represented by arrows **35**, and **51–53** will predominate over the magnetomotive forces represented by arrows **38** and **54–56** so that there will be a saturating flux in the legs **21**a, **21**b in the clockwise direction and there will be a local saturating flux in the legs **21**c and **21**d in the counterclockwise direction. The magnetomotive forces applied to the respective legs will be seen to be opposing with respect to the coupling gap **61** of head unit **21**, and a similar condition will exist for the other head units.

A signal winding is indicated diagrammatically at **70** which links the base leg portions such as indicated at **21**e of all of the head units with the same number of turns. When the legs of a given head unit are saturated, the head unit is in a signal blocking condition and there is inadequate signal flux or other required recording flux at the coupling gap **61** to produce an effective recording on the magnetizable record medium such as surface **11**a of drum **11** in FIG. 4.

Referring to FIGS. 3A and 3B, it will be observed that at time t_1 head unit **25** is being switched from one polarity of saturation to the opposite polarity of saturation, and accordingly this head unit is in a signal transmitting condition so as to effectively record an instantaneous value of signal on the associated channel of the record medium. At time t_2, head unit **24** is being switched from a positive polarity of saturation to a negative polarity of saturation as represented in FIGS. 3A and 3B while head unit **25** and the other head units are in a saturated or signal blocking condition. At times t_3, t_4 and t_5, head units **23**, **22** and **21**, respectively, are being switched from a positive polarity of saturation as represented in FIGS. 3A and 3B to a negative polarity of saturation, and at times t_6, t_7 and t_8, head units **28**, **27** and **26** are switched from a negative polarity to a positive polarity of saturation as represented in FIGS. 3B and 3C. At time t'_1 the next half cycle begins with the switching of head unit **25** and a further half cycle takes place with the switching of head units **24**, **23**, **22**, **21**, **28**, **27** and **26** at uniform intervals and in the sequence named just as in the previous half cycle. During the second half cycle, however, head units of the first group are switched from negative saturation to positive saturation as represented in FIGS. 3A and 3B while the head units **26**, **27** and **28** of the second group are switched from positive saturation to negative saturation. At time t''_1, a new cycle begins with the switching of head unit **25** from positive to negative saturation once more.

It will be observed that in the example given in FIGS. 3A through 3C, the graded magnetomotive forces applied to the respective head units have a generally rectangular or substantially trapezoidal configuration, that is the three

segments of the waveform in each half cycle together with the base line define a trapezoid. In the illustrated arrangement, the sloping segments of each half cycle of the waveform occupy one-eighth of a cycle each while the constant amplitude segments occupy one-fourth cycle. Thus, depending on the scale of the waveform plot, the waveform has a generally rectangular appearance. Each half cycle of the sweep waveform of FIG. 3B has a substantially triangular configuration and the positively and negatively sloping segments of each half cycle are of equal extent so that the triangular waveform is substantially symmetrical. It will be observed that with these waveform configurations, the interval between successive switching times such as t_1, t_2, t_3 . . . t_8 are all substantially equal and that the interval between t_8 and t'_1 and between all of the successive switching times are equal.

In FIG. 3A waveform curve **71** represents the component due to the graded windings such as **30** of the magnetomotive force variation as a function of time in legs **21**a through **21**d, while waveforms **72** through **74** similarly represent the graded winding component of the magnetomotive force variation in the corresponding legs of head units **22**, **23** and **24**. The waveforms in FIG. 3C representing the graded winding component of the magnetomotive force variation in the legs of head units **26–28** have been designated by the reference numerals **76**, **77** and **78**, respectively. The curves **76–78** are produced by graded windings such as graded winding **80** linking the head unit legs **26**a–**28**a as indicated in FIG. 2. The leg **25**a of head unit **25** is not linked by the graded windings so that the only magnetomotive force supplied to this leg is that of the sweep winding **31**. The head unit **25** is thus switched at the times that the sweep waveform **82** crosses the zero axis in FIG. 3B, i.e. at times t_1, t'_1, t''_1, etc.

Referring to FIG 4, an image printing system is illustrated wherein the head **10** receives graded winding excitation current from a component **90** and sweep waveform current from a component **91**. Component **90** may supply current to windings **30**, **41**, **42** and **43** in series as indicated diagrammatically by line **93** and may supply a further excitation current via line **94** to graded windings such as **80** of the respective legs of head units such as **26–28** in series. The current waveforms and phase are such as to produce the magnetomotive waveforms indicated in FIGS. 3A and 3C in the respective legs. Similarly as indicated by line **95**, component **91** may supply sweep current to windings **31**, **44**, **45** and **46** in series so as to produce the magnetomotive force waveform indicated in FIG. 3B in each of the legs of the successive head units. The common signal winding **70** is illustrated as receiving successive lines of an image signal from a source **97**. By way of example, the image signal may be obtained by helically scanning a visual image without substantial retrace interval between the successive lines of the visual image. Where the successive gaps **61** of the head assembly **10** lie in a plane parallel to the axis of drum **11**, the rate of rotation of the drum **11** may be coordinated with the pitch of the helical scanning of the visual image so that the lines of magnetization recorded across the magnetizable medium **11**a are essentially rectilinear with respect to the direction of movement of the record medium. By way of example, during helical scanning of a source visual image, the visual image may be scanned along successive substantially horizontal lines and the scanning device may generate a sync signal at the end of each horizontal scan which signal may be supplied as indicated by line **98** to a control source **99**. The control source **99** may then initiate and control operation of the sweep waveform generator **91** and the graded winding excitation generator **90** to produce the magnetomotive force waveforms of FIGS. 3A–3C. Suitable phase shifting circuits may, of course, be associated with components **91**, **90** and **99** so as to initially adjust the operation of the system. If desired, the drum drive circuits indicated at **100** may receive synchronizing pulses from control source **99** also. The mechanical coupling between the drum drive circuits **100** and the axis of drum **11** is indicated by the dash line **101.**

In operation of the system, the image signal source **97** may supply successive horizontal lines of a visual image such as a printed page or a picture by typical facsimile techniques. Alternatively television type information at a frame rate of 30 frames per second, for example, may be supplied. As a third example, a visual image may be stored digitally by means of a digital computer memory and read out line by line to the head assembly **10** for recording on the drum **11.** If the surace speed of the drum is 90 inches per second and the time for scanning of a line of the image information is 63 microseconds, for example, it will be seen that the movement of the surface of the drum will produce only a negligible slope of the recorded lines of the image on the recorded medium surface **11***a*.

As indicated in FIG. 4, the recorded magnetic image may be dusted with magnetic powder from a source **105** after which the magnetic powder may be transferred to a web **107** of paper or the like which may move in the direction of arrow **108** at a surface speed substantially identical to the surface speed of the drum **11.** The web **107** may travel from a supply coil **110** to a take-up coil **111**, and the powder may be suitably affixed to the paper web prior to coiling at **111.** After transfer of the powder image to the web **107** by means of pressure roll **112** any excess powder may be removed from the drum by suitable means diagrammatically indicated at **114**, and the magnetic medium **11***a* may be erased by means of an erase head diagrammatically indicated at **115.**

FIG. 5 illustrates one type of record format produced on a web such as indicated at **107** by the system of FIG. 4. In this embodiment web material **107** may contain successive image fields such as indicated at **117–119** each with a width of two inches and a length of 1.5 inches, for example (aspect ratio ¾). Each line may be recorded in an interval of 63 microseconds, and there may be 256 lines arranged successively along the length of the web for each field. A field such as field **118** may be recorded over an interval of 16.7 milliseconds corresponding to a rate of 60 fields per second and a surface speed of the drum or disk **11** of 90 inches per second. The system of FIG. 4 may print successive pictures at **117, 118,** and **119,** for example.

FIG. 6 represents a second type of record format on the web **107** of FIG. 4. This embodiment may be termed a page printer. Thus a page of information may occupy a region such as indicated at **122** on the web **107**, the region **122** having a width of 8 inches and a length dimension of 10 inches. Each line of the region **122** may be recarded during an interval of 63 microseconds, and the region **122** may correspond to 256 lines on the drum **11** recorded over an interval of 16.7 milliseconds.

As a third example, the head **10** may be operated to scan a line on the web **107** over an interval of 630 microseconds and so as to record a page 10 inches long during an interval of 167 milliseconds. In this case 6 pages would be recorded per second, and the surface speed of the drum **11***a* and of the web **107** would be 60 inches per second. This compares with a surface speed of 600 inches per second for the embodiment of FIG. 6.

FIG. 7 represents a modified sweep waveform wherein there is superimposed on the waveform **82** of FIG. 3B successive pulse waveforms which serve to precisely determine the switching times of the successive cores. Thus, for example, the positive going portion of pulse **125** of waveform **124** in FIG. 7 may occur substantially at the time t'_2 indicated in FIG. 3B so as to precisely determine the time of switching of the head unit **24.** Similarly pulse **126** may occur at time t'_3 and pulse **127** may occur at time t'_4. As indicated in FIG. 7, when the head units are being switched from positive to negative polarity, the corresponding pulses such as **129–131** in FIG. 7 have negative going portions occurring at times such as that corresponding to t'_6, t'_7 and t'_8 in FIG. 3B. The

sweep waveform of FIG. 7 is useful where exceptionally precise timing is required for activation of each head unit. The pulse source for generating pulses such as indicated at **125–131** and superimposing the same on the sweep waveform would be incorporated within the generator **91**, and FIG. 4 may be taken as specifically illustrating this arrangement as a second embodiment.

For symmetrical loading of the graded winding excitation circuits supplying conductors **93** and **94**, the graded winding **80** may link an additional magnetic core unit so as to have the same configuration as the graded winding **30.** It would not be convenient to have this core unit in scanning relation to the magnetizable record medium where the head unit would switch at time t_5, since head unit **21** switches at this time.

With respect to the embodiment of FIG. 4, it will be understood that the head assembly **10** may be angularly adjustable in a plane tangent to the surface **11***a* so that the line of gaps **61** may be tilted with respect to the direction of movement of the surface **11***a* rather than being at right angles thereto. The angle of such tilting of the head assembly **10** may be such that a straight line parallel to the axis of the drum **11** is generated on the magnetizable surface **11***a* during each scan of the successive head units of the heat assembly **10** (compensating for the drum motion during the time of one scan).

In order to fix the magnetic powder to the web **107**, the magnetic powder from source **105** in FIG. 4 may be coated with thermoplastic material which is melted by a heated roller such as that indicated at **112.** Alternatively, the web **107** may have its surface treated with a somewhat adhesive material which has an affinity for the magnetic powder on the magnetic surface **11***a*, the image transferred to the web **107** being set or fixed by heat or chemical action.

Referring to the embodiment of FIG. 7, the timing pulses such as indicated at **125–131** may be derived from the clock pulses of a computer providing the image signal source **97.** The clock pulses from the computer may be supplied via line **98** so as to lock the scanning of the head assembly **10** into synchronism with a "master clock." It has been noted that as each core changes its direction of magnetization a voltage pulse is induced in the sweep (and graded) windings. These pulses can be used to lock the associated apparatus to the core switching sequence.

For the examples given herein there may be about **256** head units in the head assembly **10.** These head units may be linked by common sweep windings and may include a central head unit which is not linked by the graded windings, and may otherwise be analogous to the simplified example of FIGS. 1, 2, and 3A–3C.

With the system of FIG. 4, multiple copies of a given recorded image signal may be made by deenergizing erase head **115** and recording head **10.** The paper supply system may operate intermittently when the same magnetic image is producing multiple copies to prevent wastage of paper.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of this invention.

I claim as my invention:

1. An image printing system comprising:

a series of magnetic transducer head units for coupling with adjacent channels across a width dimension of a magnetizable medium and having respective cores including saturable magnetic material controlling a transducing operation with respect to said record medium,

means comprising a substantially linearly graded winding having respective numbers of turns differing by successive substantially equal increments coupled to the cores of the successive transducer head units for sequentially and cyclically switching the saturable magnetic material thereof to cause the series of head units to cyclically scan the width dimension of the magnetizable medium,

means for supplying a video signal to said head units having a line repetition rate corresponding to the rate of scanning of the width dimension of the magnetizable medium by said series of head units, and

means for coacting with the magnetizable medium for automatically producing a visible copy of the video signal recorded thereon by said series of head units.

2. A system accordng to claim **1** with means for applying an alternating current of a generally rectangular waveform to said substantially linearly graded winding for providing substantially linearly related first alternating magnetomotive forces in the respective cores, and means for applying a substantially symmetrical generally triangularly shaped magnetomotive force waveform to each of said magnetic cores which is of a phase relative to the respective first magnetomotive forces to sequentially switch the saturable magnetic material of the respective cores at substantially uniform time intervals.

3. In an information processing apparatus,

magnetic core units including respective variable permeability core portions of controllable permeability for switching between a signal blocking condition and a signal transmitting condition, and for coupling with respective regions of permanently magnetizable material,

the respective core units each having a signal flux transducer element and a signal flux transmission path for effectively transmitting signal flux between the corresponding region of permanently magnetizable material and the transducer element only in the signal transmitting condition of the associated variable permeability core portion,

first magnetomotive force applying means coupled to the respective variable permeability core portions of the respective core units for applying thereto respective different substantially linearly graded values of magnetomotive force, and

second magnetomotive force applying means coupled to the variable permeability core portions of the

respective core units for applying substantially equal magnetomotive forces thereto,

the relative waveforms of the magnetomotive forces produced by the first and second magnetomotive force applying means in the respective core units being such as to sequentially switch the variable permeability core portions of the respective core units to signal transmitting condition and to activate the signal flux transmission paths of the core units at substantially uniform time intervals,

a movable element having said permanently magnetizable material thereon, said core units each being disposed in coupling relation to one of a series of adjacent channels on the magnetizable material, means for supplying an image signal to the signal flux transducer element of each of the core units having a given line repetition rate, the sequential switching of the variable permeability core portions of the respective core units occurring cyclically at a repetition rate corresponding to the line repetition rate of the image signal to record a field of the image signal as a series of lines on the permanently magnetizable material, and means coacting with the recorded image field on the magnetizable material for producing at least one visible copy thereof.

4. The apparatus of claim **3** with means for rotating said element to move said magnetizable material past said magnetic core units at a speed correlated with the line repetition rate of the image signal to record a field of the image signal on the magnetizable surface with a predetermined aspect ratio.

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J. RUSSELL GOUDEAU, Primary Examiner

U.S. Cl. X.R.

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