

United States Patent

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[54] MAGNETIC DOMAIN PROPAGATION ARRANGEMENT

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[52] U.S. Cl. 340/174 TF, 340/174 SB, 340/174 SR

[51] Int. Cl. G11c 19/00, G11c 11/14

[58] Field of Search 340/174 TF

[56] References Cited

UNITED STATES PATENTS

3,518,643 6/1970 Perneski 340/174 TF

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[57] ABSTRACT

A single electrical conductor to which an AC signal is applied causes oscillation of a single wall domain in a substrate of magnetic material in which such domains can be moved. The presence of a DC current in auxiliary conductors to either side converts the oscillation to displacement along the axis of the single conductor. A reversal of the polarity of the DC currents reverses the direction of displacement of domains.

7 Claims, 4 Drawing Figures

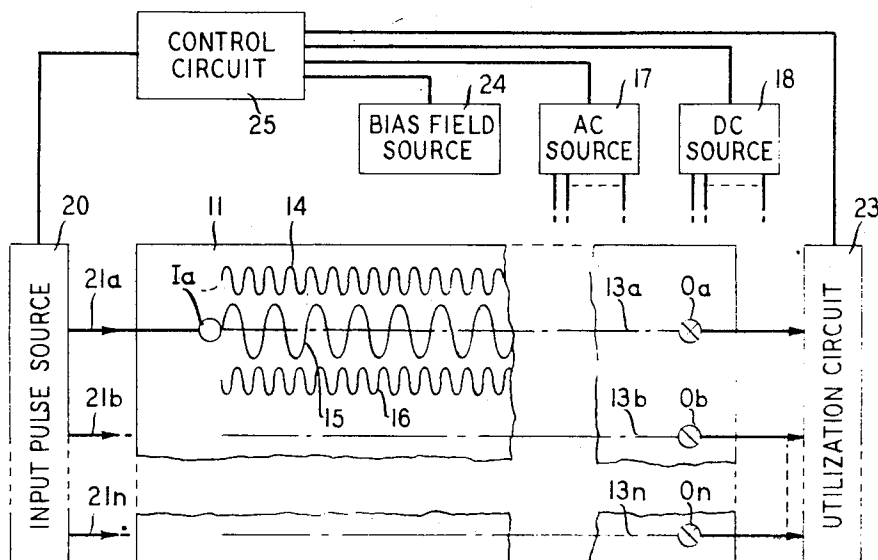


FIG. 1

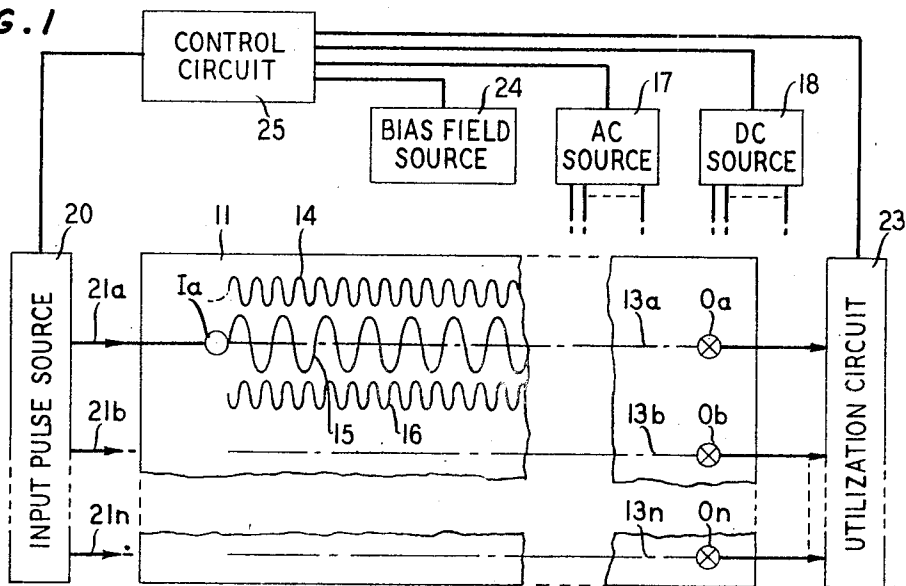


FIG. 2

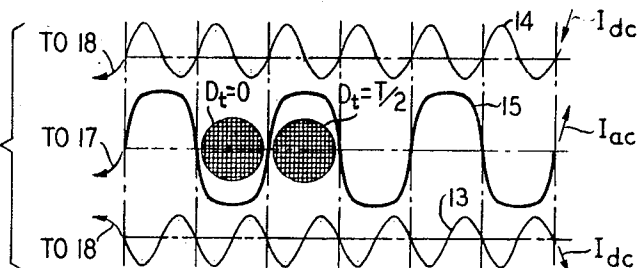


FIG. 3

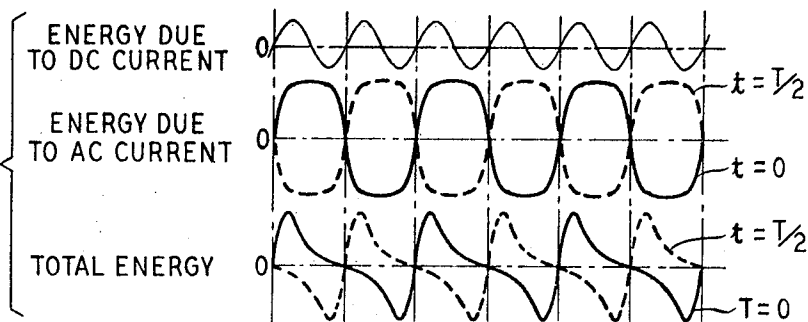
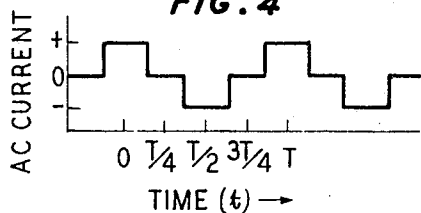


FIG. 4



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MAGNETIC DOMAIN PROPAGATION ARRANGEMENT

FIELD OF THE INVENTION

This invention relates to data processing arrangement and, more particularly, to such arrangements including a material in which single wall domains can be moved.

BACKGROUND OF THE INVENTION

A single wall domain is a magnetic domain encompassed, in the plane of a material in which it can be moved, by a domain wall which closes on itself to form a stable entity free to move in the plane. A typical material for such an arrangement is a rare earth orthoferrite or a garnet crystal having a preferred direction of magnetization along an axis out of the plane of movement, nominally normal to the plane. It is convenient to designate one direction along that axis (viz, the positive direction) as the direction of the magnetization of the domain, the remainder of the material having its magnetization in the negative direction. Such a convention permits a domain to be represented as an encircled plus sign in a field of negative signs or, simply, as a circle. A single wall domain and an arrangement for manipulating such domains are disclosed in U.S. Pat. No. 3,460,116 of A. H. Bobeck, U. F. Gianola, R. C. Sherwood, and W. Shockley, issued Aug. 5, 1969.

Single wall domains in a sheet of material are constrained to a given diameter typically by a bias field of a polarity to constrict domains—a negative polarity according to the assumed convention. Domains are moved in the sheet by a field (viz, a field gradient) which is provided in positions consecutively offset from the position occupied by a domain.

Field gradients for moving domains are provided generally by pulses applied to an array of conductor loops adjacent the surface of the material in which the domains are moved. By pulsing a succession of conductors consecutively offset from the position occupied by a domain, consecutively offset gradients are established for causing domain displacement. In practice, the conductors are interconnected serially in three sets to provide a familiar three-phase shift register operation for domain patterns. A propagation arrangement of this type is disclosed in U.S. Pat. No. 3,460,116, supra.

It has been difficult to achieve conductor arrays with geometries suitable for the movement of minute domains. In order to generate fields suitable for moving domains, minimum currents must flow in the conductors of the array. This current-carrying requirement imposes a minimum cross-sectional area on each conductor. For achieving a suitable cross section, thin conductors are formed by photolithographic techniques and plated, thereafter, to a suitable thickness. The plating process results in a widening of the conductors, as well, causing short circuits which are difficult to avoid when the array is dimensioned for moving domains having diameters on the order of microns (viz, $2\ \mu$). If the conductors are spaced further apart to avoid short circuits, packing density is sacrificed.

A simplification of the conductor geometry leads to an acceptable conductor spacing. U.S. Pat. No. 3,506,975 of A. H. Bobeck and R. F. Fischer, issued Apr. 14, 1970, is directed at one such geometry simplification. The conductors in the circuits of that patent are generally zigzag in geometry, and are pulsed consecutively for moving domains along a channel defined by a succession of conductors. With such circuits, suitably thick conductors are achieved without sacrificing packing density.

A domain channel which is defined by a succession of electrical conductors, on the other hand, is subject to a number of practical constraints. A most important constraint is the fact that certain types of channel geometries as, for example, a closed loop geometry for recirculating information are achieved either by having conductors cross over one another or by a relatively complicated geometry in which a conductor requires a mirror image return path for generating the requisite fields. The former requires a three-dimensional conductor array which is relatively costly. The latter necessitates

a redundant wiring arrangement which is wasteful of space in that domain interactions are such as to permit adjacent channels to be more closely spaced than such a redundant wiring pattern permits. Moreover, the latter also necessitates an increase in the length of the conductors at each bit location attended by an increased line resistance and, thus, voltage.

My copending application Ser. No. 49,272, filed June 24, 1970 describes conductor arrangements which avoid such constraints. An arrangement in accordance with the present invention also avoids the constraints and permits the reversal of the direction of propagation as well.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with this invention, a single wall domain is displaced in a slice of a suitable magnetic material along an axis defined by three serpentine-shaped electrical conductors to a central one of which an AC signal is applied. DC currents are maintained on the remaining two conductors which have a period twice that of the central conductor. A domain advances by moving to consecutive energy minima, generated at positions consecutively offset with respect to a domain, as the signal alternates.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic illustration of a domain propagation arrangement in accordance with this invention;

FIG. 2 is a schematic illustration of a portion of the arrangement of FIG. 1 showing consecutive magnetic conditions therein during operation;

FIG. 3 is a graph of the energy distributions in the arrangement of FIG. 1 for achieving domain displacement; and

FIG. 4 is a graph of AC current applied during operation of the arrangement of FIG. 1.

DETAILED DESCRIPTION

FIG. 1 shows a domain propagation arrangement in accordance with this invention. The arrangement includes a sheet or slice 11 of a magnetic material in which single wall domains can be moved.

A plurality of domain propagation channels 13a, 13b, ..., 13n are defined in slice 11 by electrical conductors adjacent the surface of the slice. Typically, the conductors are deposited on a glass substrate and juxtaposed with the slice. Alternatively, the conductors are deposited directly on slice 11.

Three conductors 14, 15, and 16 are employed, illustratively, to define a single domain propagation channel as shown for channel 13a in FIG. 1. Conductor 15 is connected between an AC source 17 and ground as indicated in FIGS. 1 and 2. Conductors 14 and 16 are connected similarly between a DC source 18 and ground. The conductors are serpentine in geometry, the period of conductors 14 and 16, illustratively, being twice that of conductor 15. Because of the geometric relationship between the conductors and the polarity of the DC pulse, a domain can be made to move to the right or to the left along channel 13b, as viewed in FIG. 1, from input to output positions designated I_i and O_i in the figure where i is a dummy variable.

The propagation mechanism is explained in detail in connection with FIGS. 2, 3, and 4. FIG. 2 shows the conductor geometry of FIG. 1 with a single wall domain D in consecutive positions occupied during one alternation of the AC signal in conductor 15. FIG. 3 shows the spatial distribution of energy contributed by the current in conductors 14 and 16 (energy due to DC current) and by the AC signal on conductor 14 (energy due to AC current). The figure shows the resultant (total energy) as well. The solid and broken curves $t=0$ and $t=T/2$ (time, T =period) represent the total energy for alternate polarity contributions of the AC signal for the start of a period ($t=0$) and for one-half period later ($t=T/2$). Consecutive positions for a domain correspond to the minimum energy positions of the total energy curve of FIG. 3 as shown in FIG. 2. FIG. 4 shows the AC current in conductor 15 versus time. It

is clear that the alternation of the AC signal provides consecutively displaced energy minima for a domain.

The DC current provides an asymmetry in the total energy curves which ensures that the domain moves in a selected direction. A reversal of the polarity of the DC signal, of course, changes the contour of the total energy curves ensuring movement in an opposite direction along channel 13a. Source 18 of FIG. 1 is reversible for this purpose.

A glance at the total energy curves of FIG. 3 also indicates a repeat pattern which defines the spacing between adjacent bit locations or domain positions. Each position so defined may be occupied by a domain or by the absence of a domain thus representing a binary one and zero for propagation.

The presence and absence of domains for propagation in this manner may be provided by a number of familiar implementations which selectively cause the separation of a domain from a source of positive magnetization in response to an input pulse. The input arrangement for channel 13a is represented by a circle 1a in FIG. 1. The arrangement is connected to a source of input pulses represented by block 20 in FIG. 1 as indicated by arrow 21a. One suitable input arrangement is shown in U.S. Pat. No. 3,460,116, supra.

The detection of domains in channel 13a similarly is represented by an encircled X (0a) in FIG. 1. Typically, a Hall probe, an electrical pickup, or optical means based on the Faraday or Kerr effects are employed. One suitable detection arrangement is disclosed in copending application Ser. No. 882,900, filed Dec. 8, 1969 for W. Strauss. In any case, the presence of a domain at an output position generates a signal which is applied to a utilization circuit represented by block 23 of FIG. 1.

In practice, the size of a domain is maintained at some nominal value by a bias field of a polarity to constrict the domain. Such a field is provided by an electrically conducting coil in which a current is passed. The coil encompasses slice 11 and is disposed in the plane of the slice. Alternatively, a permanent magnet is used. The source of the bias field is represented in FIG. 1 by block 24.

Sources 17, 18, 20, 24 as well as circuit 23 are connected to a control circuit 25 for activation and synchronization. The various sources and circuits may be any such elements capable of operating in accordance with this invention.

A propagation arrangement of the type shown in FIG. 1 operates to move 100 micron diameter domains in a slice of thulium orthoferrite 1 centimeter $\times$ 1 centimeter $\times$ 50 microns thick. The conductors are 20 microns wide and 5 microns thick. An AC signal 0.1 ampere is applied to the central conductor and a DC current of 0.1 ampere is maintained on the remaining conductors. A bias field of 1,600 A./m. is maintained. Bit rates of 1 megahertz are achieved. The spacing between the conductors is 120 microns. A reversal of the DC current (see arrows I_{dc} of FIG. 2) caused reversal of the direction of domain displacement. Of course, the same circuit also moves domains of substantially smaller diameter of 20 microns for example. Also the circuit can be scaled down by a

factor of 20 for the movement of about 2 micron domains.

What has been described is considered only illustrative of the principles of this invention. Therefore, other embodiments can be devised by those skilled in the art in accordance with those principles within the spirit and scope of this invention. For example, the invention has been described in terms of a particular relationship between the periods of the conductor to which the AC signal is applied and those in which the DC current is maintained. That relationship may be different so long as an asymmetry in the total energy curves results in domain displacement. A spatial periodicity of an order higher than two to one can be used to achieve the same result. The chosen relationship, however, provides a maximum displacement of domains. Higher harmonics, moreover, require higher resolution photolithography. Moreover, it should be clear that the absence of either the AC or the DC current in any channel of FIG. 1 prevents domain movement there thus leading to a selective propagation arrangement.

What is claimed is:

1. A domain propagation arrangement comprising a slice of material in which single wall domains can be moved, and means for defining in said slice a channel for domain movement, said means comprising a symmetrical serpentine first conductor aligned along said channel, means for providing an AC current in said first conductor for generating a first periodic energy configuration along said channel, and means for selectively generating in said channel a second periodic energy configuration offset with respect to said first configuration for moving domains in a first direction in said channel.
2. A domain propagation arrangement in accordance with claim 1 wherein said last-mentioned means comprises second and third conductors on first and second sides of said first conductor, and a DC source connected to said conductors.
3. An arrangement in accordance with claim 2 wherein said first, second and third conductors bear a periodic relationship to one another to produce in said slice an asymmetric energy condition for incrementally displacing domains for each alternation of said AC current.
4. An arrangement in accordance with claim 3 wherein said central one of said conductors has a first period and each of said second and third conductors has a second period twice said first period.
5. An arrangement in accordance with claim 4 wherein said slice is characterized by a preferred direction of magnetization normal to the plane of said slice.
6. An arrangement in accordance with claim 5 also including means for selectively providing said domains in said channel and means for selectively detecting domains in said channel.
7. An arrangement in accordance with claim 2 wherein said DC source is reversible for generating second and third periodic energy configurations offset with respect to said first configuration for moving domains in first and second directions in said channel.

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