Sept. 15, 1970 A. H. BOBECK 3,529,303

DOMAIN PROPAGATION ARRANGEMENT

Filed Nov. 12, 1968

FIG. 1

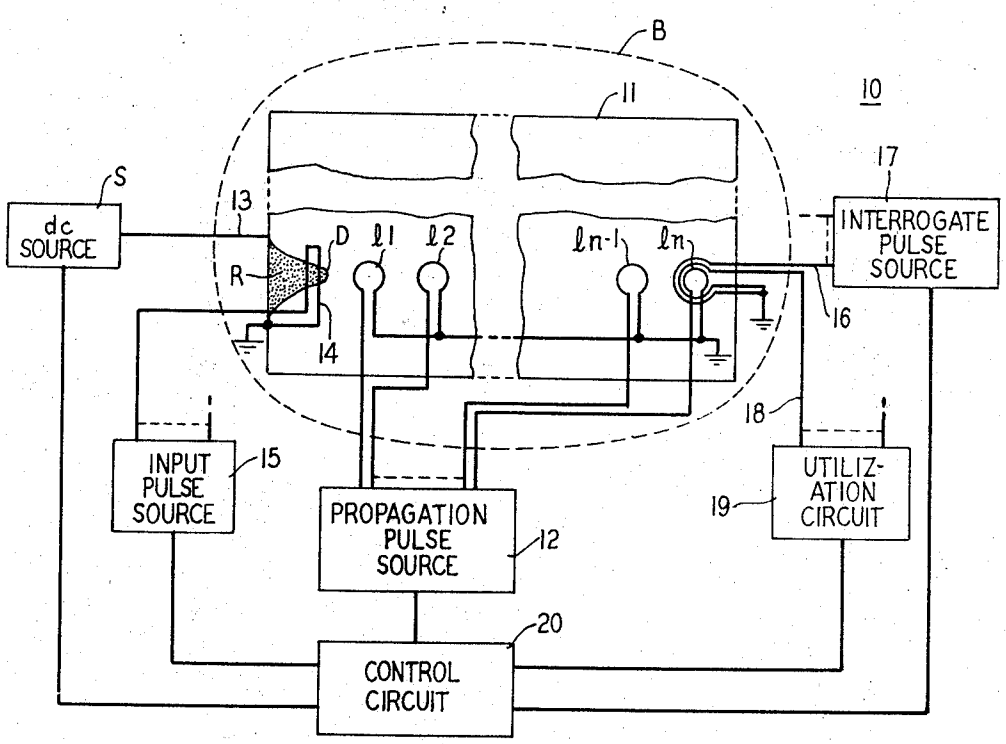


FIG. 2

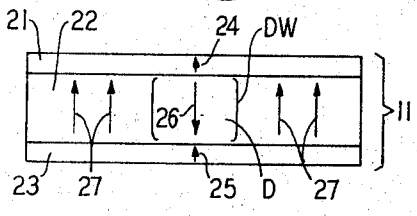


FIG. 4

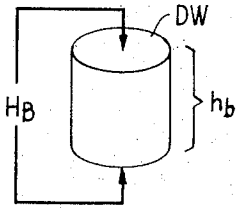
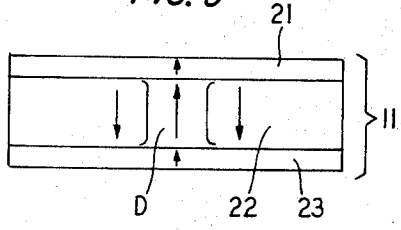


FIG. 3



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DOMAIN PROPAGATION ARRANGEMENT

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U.S. Cl. 340—174 6 Claims

ABSTRACT OF THE DISCLOSURE

An external means for supplying a bias field of a polarity to contract single wall domains employed to insure the stability of single wall domains in some orthoferrite sheets has been found to be unnecessary if the surface layers of the sheet are prepared so that those surfaces are permanently magnetized normal to the sheet and exchange-coupled to the body of the sheet.

FIELD OF THE INVENTION

This invention relates to data processing arrangements and, more particularly, to such arrangements employing magnetic media in which single wall domains can be propagated.

BACKGROUND OF THE INVENTION

A single wall domain is a magnetic domain bounded by a domain wall which closes on itself and has a geometry independent of the boundary of the sheet in which it is moved. Such a domain conveniently assumes the shape of a circle (viz., cylinder) in the plane of the sheet and has a diameter determined primarily by the material parameters. The Bell System Technical Journal, vol. XLVI, No. 8, October 1967, at pages 1901 et seq., describes the propagation of single wall domains in a propagation medium such as a sheet of a rare earth orthoferrite.

One mode of operating with single wall domains is referred to as the "bias mode" because a bias field of a polarity to contract domains is generated in the material under normal operating conditions in order to maintain constant the diameters of single wall domains therein. For a sheet of orthoferrite, which is characterized by a preferred direction of magnetization essentially normal to the plane of the sheet, the bias field also is essentially normal. If, for example, we adopt the convention that a single wall domain has its magnetization in a positive direction along an axis normal to the plane of the sheet, the domain can be represented as an encircled plus sign and the bias field is taken to be in a negative direction along that axis.

The bias field is usually generated by a coil encompassing the sheet, in which single wall domains are moved, and oriented in the plane of that sheet. A suitable drive arrangement provides a current in the coil for generating the field in a controllable manner.

BRIEF DESCRIPTION OF THE INVENTION

It has been found that the bias field can be provided by preparing the surfaces of the sheet in which domains are moved such that the surface layers are permanently set magnetically along a first preferred direction of magnetization and exchange coupled to the body of that sheet. Bias mode operation with domains of essentially constant diameter is thus provided in the absence of an external bias implementation. In one embodiment of this invention a sheet of terbium orthoferrite which is bismuth doped is prepared with surface layers permanently set by a magnetic field. Single wall domains moved in such a sheet are somewhat spherical in shape and have an essentially constant diameter.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic representation of an arrangement in accordance with this invention; and

FIGS. 2, 3, and 4 are schematic representations of portions of the arrangement of FIG. 1.

DETAILED DESCRIPTION

FIG. 1 shows a domain propagation arrangement **10** in accordance with this invention. The arrangement includes a magnetic sheet **11** in which single wall domains are moved. Only a single channel for domain propagation is shown. It is to be understood, however, that the channel is only representative and that others may be defined in a similar manner either parallel to the one shown or at an angle thereto in accordance with the teaching of the above-mentioned publication.

The channel is defined illustratively by a succession of conductor loops, *l1*, *l2*, *l3* . . . *ln*, which are pulsed to generate consecutive localized magnetic fields (gradients) to attract a single wall domain from an input to an associated output position. The conductor loops are connected between a propagation pulse source **12** and ground to this end.

Single wall domains are introduced into a domain propagation channel from a source of domains illustratively comprising a region R of positive magnetization in accordance with the adopted convention. Region R is encompassed by a conductor **13** which is connected between a D.C. source S and ground. A hairpin conductor **14** is associated with source **13** to separate a portion D thereof when pulsed. Conductor **14** is connected between input pulse source **15** and ground. When source **15** pulses conductor **14**, portion D is separated from region R and becomes a single wall domain for propagation. Conductor **13** oeprates to restore region R to its normal shape when the pulse in conductor **14** terminates. If a pulse is absent in a particular input time slot, no domain is generated of course. Binary ones and zeros thus are represented by the presence and absence of single wall domains respectively.

A domain pattern thus repersentative of information is moved along a propagation channel, by the propagation loops pulsed in a familiar three-phase manner, towards an output position.

An output position is defined illustratively by a conductor **16** which loops the rightmost (terminal) propagation loop (*ln*) as viewed in FIG. 1. Conductor **16** is connected between an interrogate pulse source **17** and ground and serves to collapse a domain present in the position so coupled. A conductor **18** also couples such terminal position. Conductor **18** is connected between a utilization circuit **19** and ground. If a domain is present in the coupled terminal position when an interrogate pulse is applied to conductor **16**, conductor **18** applies a pulse to utilization circuit **19**. The interrogate pulse is usually applied synchronously with an input pulse and a selected propagation pulse and the various circuits and sources are connected to a control circuit **20** for appropriate activation and synchronization.

The various circuits and sources may be any such elements capable of operating in accordance with this invention.

Operation of a domain propagation device in the bias mode utilizes a bias field normal to the plane of sheet **11**. Such a field is normally provided by a current in a coil in the plane of sheet **11** occupying the position of imaginary circle B. In accordance with this invention, domains can be moved in sheet **11** with essentially constant diameters in the absence of such a bias field. The equivalent of the bias field in provided by the structure of sheet **11**.

A simple way to demonstrate the effectiveness of a structure in accordance with this invention in providing

a bias equivalent field is to examine that structure under different magnetic conditions, express the differences in conditions in mathematical terms, and compare the resulting terms with an expression for a generated bias field. With this context in mind, we can examine the structure of sheet **11** as shown in an imaginary side view in FIG. 2. Sheet **11** may be thought of as including three separate layers which may in fact be a single body as is discussed further hereinafter. The three layers are designated **21**, **22**, and **23** in FIG. 2. Layers **21** and **23** have the property that the magnetization therein can be set permanently while that of layer **22** can be changed at specified fields. Layers **21** and **23** are assumed to have magnetization directed upward as indicated by the upward directed arrows **24** and **25** in FIG. 2. Layer **22**, on the other hand, is assumed to have its magnetization directed downward, as indicated by downward directed arrow **26** in FIG. 2, in the single wall domain which is designated D as in FIG. 1. The remainder of layer **22** has its magnetization directed upward as indicated by the upward directed arrows **27**. It is clear that a domain wall exists between domain D and the remainder of layer **22** as well as between domain D and each of the surface layers **21** and **23**. The domain wall is designated DW in FIG. 2.

FIG. 3 shows the magnetization in domain D and the remainder of layer **22** reversed from that shown in FIG. 2. It is clear from FIG. 3 that no domain wall exists between domain D and the magnetization of layers **21** and **23**.

Consider, in this context, the domain wall energy that can exist in the interfaces of layers **21** and **22** and layers **22** and **23**. It is clear that in FIG. 2 the total wall energy at these interfaces is

$$\epsilon_\omega = 2\pi r^2 \sigma_\omega \tag{1}$$

where σ_ω is the wall energy per unit area and r is the radius of the domain. The force acting to change the domain size is given by

$$\frac{\partial \epsilon_\omega}{\partial r} = 4\pi r \sigma_\omega \tag{2}$$

This can be compared to the force produced by a conventionally applied bias field H_A

$$\frac{\partial \epsilon_A}{\partial r} = 4\pi r h M_s H_A \tag{3}$$

where h is the layer **22** thickness and M_s is the saturation magnetic moment of layer **22** material. If we normalize each of forces (2) and (3) in terms of an applied bias field H_A we recognize a new effective field which we can designate as H_W

$$H_w = \frac{\sigma_\omega}{h M_s} \tag{4}$$

We see now that the wall energy tends to act as a bias field and that field is not dependent on the domain size.

If we let the average value of this field be H_B, then a thickness h_b can be selected for a particular orthoferrite by

$$h_b = \frac{\sigma_\omega}{M_s H_B} \tag{5}$$

At this thickness, shown in FIG. 4, the cylindrical domains are stable and will remain stable without the necessity of an external applied field.

A convenient structure of the type shown in FIG. 2 is prepared, for example, by suitably polishing a sheet comprising a crystal of terbium orthoferrite ($TbFeO_3$) plus bismuth (one percent). Typically, the sheet has a thickness of 1.7 mils and each surface has a strain layer of one micron thickness to provide a coercivity there for enabling a magnetization condition which is only negligibly changed during operation. Single wall domains having diameters of 2.0 mils have been moved in such a sheet by propagation fields of about 10 oersteds generated as indicated in FIG. 1.

There are alternative structures wherein additional layers are deposited on the surfaces of a suitable sheet of material in which single wall domains can be moved. For example, high coercivity layers of magnetoplumbite can be deposited on terbium orthoferrite to this end. All that is necessary is that the surface layers, whether grown or deposited, be of sufficiently high coercivity to remain set permanently during operation and that the layers be exchange-coupled to the body layer.

What has been described is considered only illustrative of the principles of this invention. Consequently, various modifications in accordance with those principles can be devised by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. A domain propagation arrangement comprising a sheet of magnetic material in which single wall domains can be moved, said sheet being characterized by a preferred direction of magnetization along an axis out of the plane of said sheet and having first and second surface layers and a body layer, each of said surface layers being effectively permanently set in a direction along said axis and exchange-coupled to said body layer, and means for moving single wall domains in said body layer in a manner to avoid changing the magnetization in said surface layer.

2. An arrangement in accordance with claim **1** wherein said axis is substantially normal to the plane of said sheet.

3. An arrangement in accordance with claim **2** wherein said sheet comprises a crystal of a rare earth orthoferrite including about one percent bismuth.

4. An arrangement in accordance with claim **3** wherein said sheet comprises a crystal of terbium orthoferrite having strained surface layers for maintaining a preset condition of magnetization therein.

5. An arrangement in accordance with claim **2** wherein said body layer comprises a rare earth orthoferrite and said surface layers comprise relatively high coercivity layers of magnetoplumbite.

6. An arrangement in accordance with claim **5** wherein said body layer comprises terbium orthoferrite.

References Cited

UNITED STATES PATENTS

3,092,813 6/1963 Broadbent ---------- 340—174

JAMES W. MOFFITT, Primary Examiner