

Sept. 30, 1969

A. H. BOBECK

3,470,547

SWITCHING CROSSPOINT ARRANGEMENT

Filed Sept. 16, 1966

3 Sheets-Sheet 1

FIG. 1

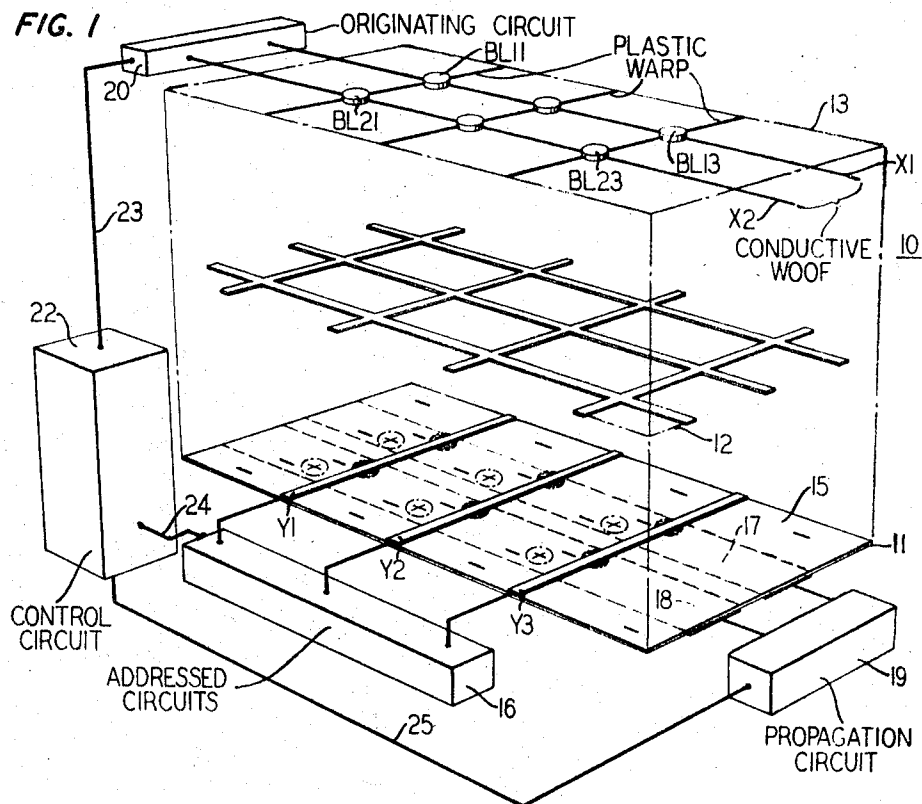
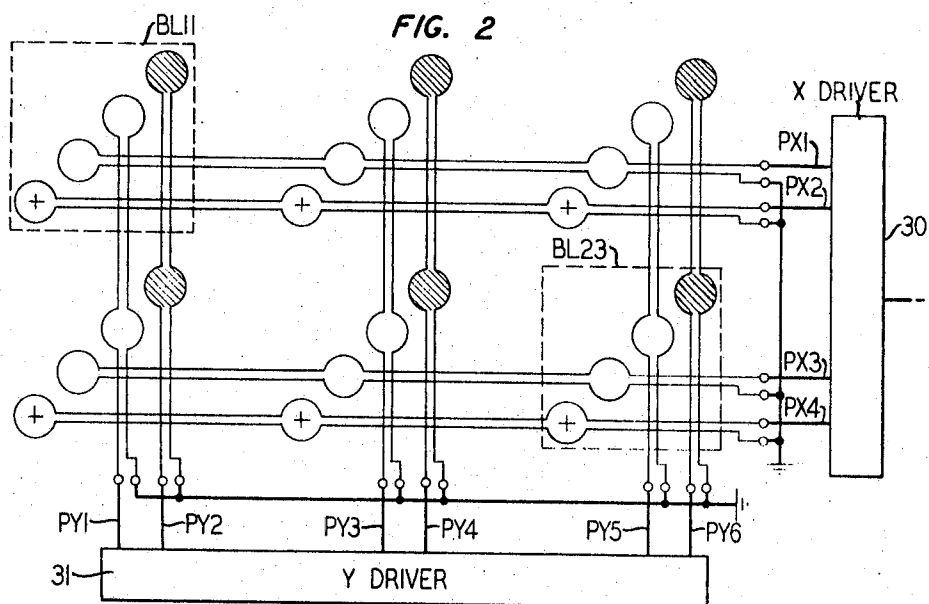


FIG. 2



INVENTOR  
A. H. BOBECK

BY *Herbert M. Shapiro*  
ATTORNEY

Sept. 30, 1969

A. H. BOBECK

3,470,547

SWITCHING CROSSPOINT ARRANGEMENT

Filed Sept. 16, 1966

3 Sheets-Sheet 2

FIG. 3

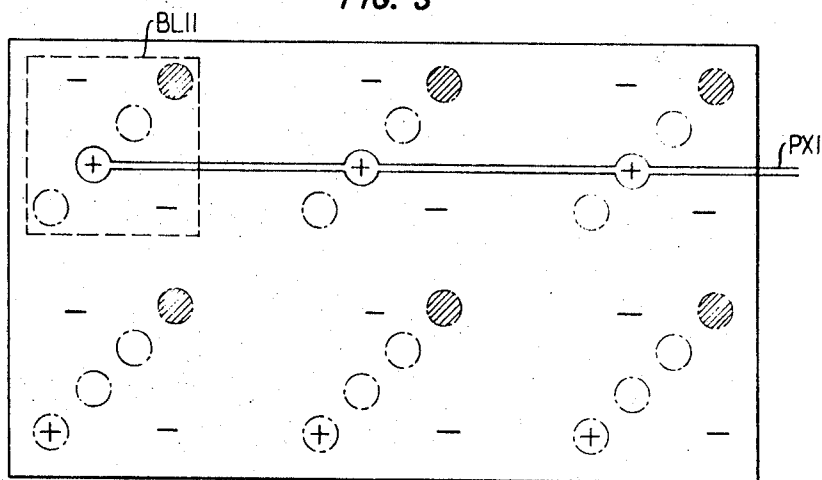


FIG. 4

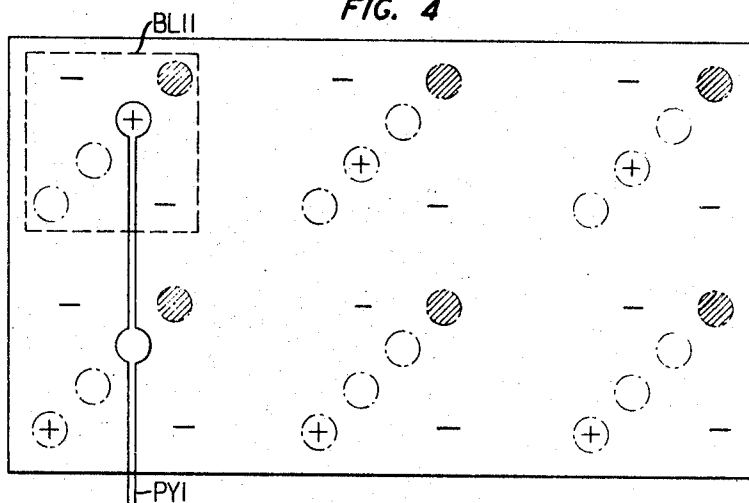
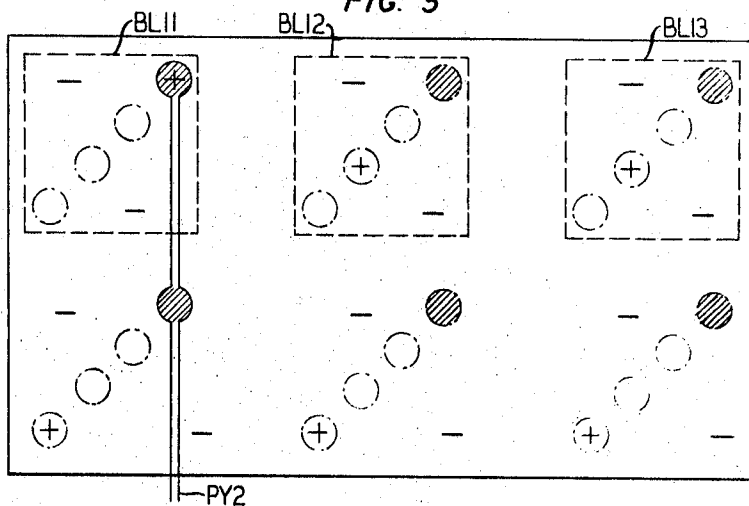


FIG. 5



Sept. 30, 1969

A. H. BOBECK

3,470,547

SWITCHING CROSSPOINT ARRANGEMENT

Filed Sept. 16, 1966

3 Sheets-Sheet 3

FIG. 6

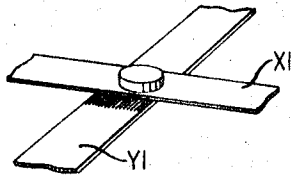


FIG. 7

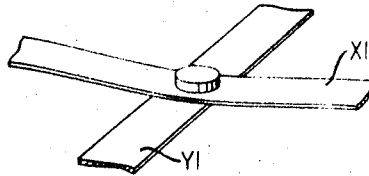


FIG. 8

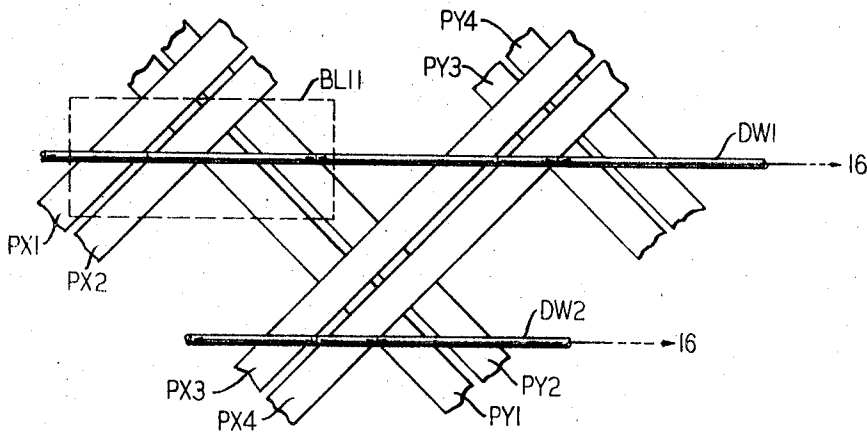


FIG. 9

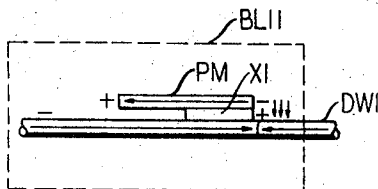
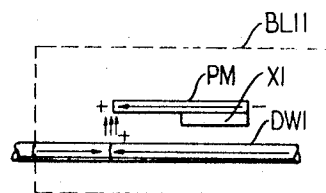


FIG. 10



1

3,470,547

## SWITCHING CROSSPOINT ARRANGEMENT

Andrew H. Bobeck, Chatham, N.J., assignor to Bell Telephone Laboratories, Incorporated, Murray Hill and Berkeley Heights, N.J., a corporation of New York

Filed Sept. 16, 1966, Ser. No. 579,905

Int. Cl. H01h 63/33

U.S. Cl. 340—174

9 Claims

### ABSTRACT OF THE DISCLOSURE

A selected one of a matrix of crosspoints defined by X and Y oriented conductors can be closed by pinching the wires together at the selected location. The movement of a magnetic domain associated with a Y conductor at each crosspoint controls the attraction of a magnet associated with the X conductor at each crosspoint.

This invention relates to switching system networks and, more particularly, to such networks including switching crosspoints.

Switching system networks have at their very heart crosspoint switches which are selectively closed for providing a speaking path between associated X and Y channels. Considerable effort has been expended to find ever better and ever cheaper crosspoints, an effort realized to be justified when one appreciates the extent to which such crosspoints are used. Even a small improvement in operating characteristics or a modest reduction in cost is eagerly sought after.

The reed switch is one type of crosspoint switch which is now widely used. The reed switch is an electromechanical device including normally spaced apart cantilevered contacts which close under the influence of a magnetic field to provide the requisite connection between coordinate channels when selected. The contacts in a reed switch are (resilient or) spring loaded for returning the contacts to the open condition when released. The spring, of course, presents an additional load which is to be overcome when a selected crosspoint is to be closed. Consequently, the pull required to close a reed switch at a selected crosspoint is greater than would be required in the absence of such a spring thus necessitating a relatively high drive. In addition, the entire cantilevered contact structure of a reed switch provides an extended closure path of limited cross section through which flux is provided for effecting the closed condition. The losses associated with the contact structure further increase the requisite drive.

It is an object of this invention to provide a new and novel crosspoint matrix having relatively low drive requirements.

The invention, in one aspect thereof, is based on the realization that a single wall (reverse) domain in a magnetic sheet provides sufficient flux in a direction normal to the plane of the sheet to close a contact of the type described. Such a magnetic sheet is also characterized in that the absence of a single wall domain in a particular location provides flux of an equal and opposite polarity for repelling the contact. Single wall domains and the movement thereof selectively in transverse directions in a magnetic sheet are described in copending application Ser. No. 579,995, filed Sept. 16, 1966, for P. C. Michaelis and in copending application Ser. No. 579,931, filed Sept. 16, 1966, for A. H. Bobeck, U. F. Gianola, R. C. Sherwood, and W. Shockley. The former application describes the storage and movement of such single wall domains in magnetic films with preferred magnetization directions in the plane of the magnetic film. The latter describes the storage and movement of single wall domains in a sheet

2

of magnetic material with a preferred magnetization direction normal to the plane of the sheet. Either arrangement is useful in accordance with the teachings of this invention.

Briefly, in accordance with one aspect of this invention, a matrix of two-position ("1" and "0") bit locations is defined in a sheet of magnetic material substantially isotropic in the plane of the sheet and having a preferred magnetization direction illustratively normal to the plane of the sheet. A single wall domain is stored in the "0" position of each bit location and a permanent magnet is associated with each "1" position. X conductors are associated with rows of permanent magnets; Y conductors are associated with columns of bit locations. When a single wall domain is moved from a "0" to a "1" position in a selected bit location, it attracts the associated permanent magnet placing the corresponding X and Y conductors in contact there. In the absence of such a selection, a repelling force is present at the "1" position maintaining the corresponding permanent magnet at a distance avoiding a connection at that crosspoint.

In accordance with another aspect of this invention, reverse domains having leading and trailing domain walls are expanded selectively from first to second positions in bit locations in domain wall wires for similarly making connections at crosspoints.

A feature of this invention is a switching network crosspoint matrix including a magnetic medium, means defining a matrix of two-position bit locations in the medium, the first position in each bit location including a reverse magnetized domain, means selectively moving magnetized domains to second positions in corresponding bit locations, magnet means associated with each second position and X and Y conductors associated with the magnet means and the magnetic medium respectively.

The foregoing and further objects and features of this invention will be understood more fully from a consideration of the following detailed discussion rendered in conjunction with the accompanying drawing wherein:

FIG. 1 is an exploded schematic view of a crosspoint matrix in accordance with this invention;

FIGS. 2, 3, 4, 5, 6, and 7 are schematic views of portions of the matrix of FIG. 1; and

FIGS. 8, 9, and 10 are schematic views of portions of another crosspoint matrix in accordance with this invention.

FIG. 1 shows a crosspoint matrix 10 in accordance with one aspect of this invention. The crosspoint matrix is composed of first, second, and third planar portions 11, 12, and 13 juxtaposed with one another. Planar portion 11 comprises, illustratively, a sheet of yttrium orthoferrite 15 with spaced apart Y conductors Y1, Y2, and Y3 thereon. The Y conductors are connected to individual circuits such as, for example, telephone subsets represented collectively as block 16 designated "addressed circuits." Such interconnections are well understood in the art and a discussion thereof is not necessary for an understanding of this invention.

Planar portion 11 also includes propagation conductors represented in FIG. 1 by conductor indications 17 and 18 in FIG. 1 and described in detail in connection with FIG. 2. Conductor indications 17 and 18 are connected to a "propagation circuit" represented by a block 19, so designated, in FIG. 1 and also discussed further in connection with FIG. 2. For the present it is assumed that the propagation circuit defines a matrix of two-position bit locations in the orthoferrite sheet. This will become clear in the discussion of that circuit in connection with FIG. 2 hereinafter. It is further assumed that one position in each of these locations is occupied by a single

wall domain. Such domains are provided in those positions by means disclosed, for example, in the aforementioned application of A. H. Bobeck et al. It is contemplated to prepare the orthoferrite sheet initially with the domains disposed as required. Consequently, input circuitry and the means for so disposing the domains are not required for continued operation of a crosspoint matrix in accordance with the teachings of this invention. Nor is a discussion of such implementations necessary for an understanding of the invention. It is sufficient to call for the presence of such domains, provided by means disclosed elsewhere and to state that the function of the propagation circuit is to move a selected domain from a first to a second position and back again on a random access basis. The specific operation of the propagation circuit to this end will be discussed after the discussion of the structure of FIG. 1 is completed.

Planar portion 12 of crosspoint matrix 10 is an apertured plastic film which overlies sheet 11.

Planar portion 13 comprises a weave of a plastic warp with respect to which electrically conducting wires X1 and X2 comprise the woof. Conductors X1 and X2 are connected to block 20, designated "originating circuit" in FIG. 1. Block 20 may also represent a plurality of telephone subsets as is well understood in the art.

Permanent magnets positioned at what is conveniently designated bit locations BL11, BL12 . . . BL21 . . . , and BL23, as will become clear, are affixed to crosspoints defined by the intersections of the warp and the woof of planar portion 13. Each magnet is positioned to correspond to the second position of a bit location in the orthoferrite sheet. Each magnet is positioned also to correspond to apertures in the plastic film of planar portion 12 in order to pass therethrough when attracted by the flux of a single wall domain when the latter is moved to a second position in a selected bit location.

The originating, addressed, and propagation circuits 20, 16, and 19 are connected to a control circuit 22 by means of conductors 23, 24, and 25, respectively. The various circuits may be any such circuits capable of operating in accordance with this invention. In the context of a telephone system, the control circuit may comprise central office switching equipment. The originating and addressed circuits may comprise telephone subsets as already stated.

FIG. 2 shows the propagation circuit represented by conductor indications 17 and 18 and block 19 in FIG. 1. The circuit is arranged illustratively for six bits. It is clear that the indications 17 and 18 of FIG. 1 represent a plurality of rows and columns of drive conductors. Specifically, the propagation circuit comprises a plurality of row conductors PX1, PX2, PX3, and PX4. Each of those conductors has a return path to ground and forms with corresponding portions of its return path circular conducting loops in rows as shown. A single wall domain is stored initially in the magnetic sheet at positions defined by the conducting loops formed by conductors PX2 and PX4 and their respective return paths. The conductors PX1, PX2, PX3, and PX4 originate at an X driver 30.

Similarly, the propagation circuit also comprises a plurality of column conductors PY1, PY2, PY3, . . . , and PY6. Each of these conductors also has a return path to ground and forms conducting loops therewith. The loops so formed are arranged in columns providing, with corresponding loops formed by conductors PX1, PX2, PX3, and PX4 with the respective return paths, a set of four loops oriented illustratively along a diagonal at each bit location as viewed in FIG. 2. The four loops in each bit location are next adjacent one another in practice but are shown spaced apart for convenience in the figure. The conductors PY1 . . . PY6 originate at a Y driver 31.

The conducting loops formed by conductors PY2, PY4, and PY6 are shown blackened in FIG. 2. The magnets associated with bit locations BL11 . . . , and BL23 shown in FIG. 1 are positioned in planar portion 13 to

correspond to those "blackened" loops. The object of the propagation circuit then is to move the single wall domain from the position in which it is initially stored to the position of the corresponding blackened loop in a selected bit location.

Let us assume that the entire sheet of magnetic material is in a magnetic condition where flux is directed downward into the plane of the sheet as represented by the minus (—) signs in FIG. 1. The single wall domains stored in first positions in the bit locations then may be represented by plus (+) signs at those first positions. The domain wall of the single wall domain may be thought of as corresponding in position to the conducting loop thereabout. Actually single wall domains may extend beyond the confines of the conducting loop as described in the aforementioned Bobeck et al. application.

A positive pulse, applied by driver 30 to conductor PX1 under the control of control circuit 22, generates a propagation field for moving the single wall domain in each bit location therealong to the position of the conducting loop defined thereby in the corresponding bit location. FIG. 3 shows an abstraction representing the conducting loops shown in FIG. 2. When conductor PX1 is pulsed, the single wall domains in bit locations in the magnetic sheet coupled thereby are moved to positions then as shown in FIG. 3.

Next a negative (for the sense shown) pulse is provided similarly on conductor PY1. The single wall domain in location BL11 is now in a location defined by the corresponding conducting loop in conductor PY1. The remaining domains in bit location BL12 associated with that conductor are not moved in response to the pulse on conductor PY1. The disposition of domains is as shown in FIG. 4.

Thereafter a negative pulse is applied similarly to conductor PY2, also under the control of control circuit 22, moving the domain in bit location BL11 to the position of the blackened loop there. The disposition of domains is as shown in FIG. 5. It is clear that only the single wall domain in bit location BL11 is in a (second) position corresponding to the position of a permanent magnet in planar portion 13 of FIG. 1.

When the single wall domain is in the initial position, conductors X1 and Y1 are spaced apart as shown in FIG. 6. When the single wall domain is moved to the second (blackened) position in selected bit location BL11, the permanent magnet in that bit location is pulled toward sheet 15 for placing conductor X1 in contact with conductor Y1 there as shown in FIG. 7. The plastic film of planar portion 12 is to insure that next adjacent magnets are not affected by the movement of a selected magnet.

Finally, a positive pulse is applied similarly to conductor PX2 for returning domains in disturbed "zero" positions, as shown in bit locations BL12 and BL13 in FIG. 5, to initial positions.

The single wall domain is returned to its initial position selectively from the "one" position as shown in bit location BL11 in FIG. 5 by a similar propagation pulse sequence on conductors PY1, PX1, PX2, and finally on conductor PY2, the latter pulse being applied to return to "one" position domains in any previously selected locations disturbed by the present selection. All pulses are applied by drivers 30 and 31 under the control of control circuit 22.

A four pulse selection sequence is applied in microseconds. The wires require milliseconds to come into contact or to move apart. Accordingly, the disturb effects are negligible. The propagation operation is entirely consistent with that described in copending application Ser. No. 579,904, filed Sept. 16, 1966, for A. H. Bobeck.

A recitation of the dimensions and operating parameters for a crosspoint matrix as shown in FIG. 1 emphasizes the advantages of such an arrangement. The magnetic sheet 15 is about one inch by one inch by thirty mils thick. A single wall domain has a diameter of about fifty mils. The plastic film of planar portion 12 is typically

two mils thick, corresponding to the normal spacing between X and Y conductors. Each permanent magnet has a diameter approximately equal to that of a single wall domain and is about thirty mils thick. The permanent magnets shown in FIG. 1 are magnetized such that the flux is directed downward therefrom as viewed in the figure. The X and Y conductors have cross-sectional areas of about two square mils sufficient to carry currents common for such circuits. A suitable attracting force of more than one gram is easily provided by a single wall domain. A repelling force of comparable magnitude is present in the absence of a single wall domain. A single wall domain is moved in available magnetic sheets by about one oersted fields provided with drive currents of the order of one ampere (through a single turn) and switching speeds on the order of microseconds are realized. This is to be compared with currents of about ten amperes required by a reed switch having, typically, on the order of twenty turns. It is clear that the matrix of FIG. 1 not only is of a convenient size and amenable to mass fabrication techniques but also permits a reduction of over an order of magnitude in drive requirements (on an ampere turn basis) over prior art circuitry operating in similar fashion.

Planar portion 11 of FIG. 1 may, alternatively, be formed by a plurality of domain wall wires which conveniently are electrically conducting also. FIG. 8 depicts a portion of such a planar wire counterpart of the embodiment of FIGS. 1 and 2 showing only a portion of the propagation circuitry therefor. Specifically, FIG. 8 shows portions of first and second electrically conducting domain wall wires DW1 and DW2 shown connected to an addressed circuit as represented by block 16 of FIG. 1 (only indicated here). A reverse domain is represented in a domain wall wire by an arrow directed to the right as viewed and bounded by vertical lines representing leading and trailing domain walls. The reverse domains are stored initially at positions corresponding to the left edge of conductors PX2 and PX4. The wires are otherwise in an initialized magnetic state represented by arrows directed to the left as viewed.

A plurality of propagation conductors PX1 . . . PX4, and PY1 . . . PY4, designated to correspond to their counterparts in the embodiment of FIG. 1 couple next adjacent portions of wires DW1 and DW2 to provide a unique expansion of only a selected reverse domain from an initial first position to a second position corresponding to the position indicated by the blackened reverse domain symbol as shown at bit location BL11 in FIG. 8. To this end, a sequence of pulses on conductors PX2, PY1, PY2, and (a negative pulse)—PX2 expands a reverse domain uniquely from an initial (first) position in bit location BL11 to encompass the second position there by the provision of step-along fields in coupled portions of the wire. Only in the bit location where the first three pulses of the propagation sequence are applied is a domain expanded to the second position. The last-mentioned pulse corrects disturbed information in nonselected locations as described hereinbefore. A sequence of negative pulses —PY2, —PY1, —PX2, and positive pulses +PY1 and +PY2 similarly selectively returns the domain to the initial condition. It should be clear that the X1 conductor shown in the embodiment of FIGS. 1 and 2 is not necessary in the embodiment of FIG. 8 and may be omitted or alternatively used for some other purposes, such as for nucleating reverse domains initially. The organization of the propagation circuitry is entirely analogous to that shown in FIG. 2.

A more complicated propagation scheme permits movement of a domain in a wire rather than the expansion of the domain as described, care being taken to advance the trailing wall of the domain synchronously.

Corresponding permanent magnets as shown in FIG. 1 are again positioned to correspond to second positions for cooperating with the embodiment of FIG. 8. Thus

closure of the selected crosspoint is effected and a talking path is established between conductor X1 of FIG. 1 and domain wall wire DW1 which may function also as conductor Y1 of FIG. 1 in this embodiment.

FIGS. 9 and 10 illustrate the attract and repel conditions in the operation of a representative bit location in the embodiment of FIG. 8. The permanent magnet PM in this embodiment is assumed magnetized as indicated by the arrow directed to the left there as viewed. The reverse domain is shown in FIG. 9 expanded to the second position in bit location BL11. As is indicated by the plus and minus signs in the figure, the reverse domain and the permanent magnet are poled in opposite directions providing the force of attraction bringing conductor X1 and conducting magnetic wire DW1 in contact there. The force of attraction is indicated by the downward directed arrows in FIG. 9.

FIG. 10 shows the domain in the first position of bit location BL11. The positive poles of the permanent magnet and the domain are positioned opposite one another and thus provide a repelling force indicated by the upward directed arrows in the figure.

The domain wall wire, typically, has a diameter of seven mils and comprises a material having a coercive force of about five oersteds to provide sufficient flux for insuring operation as described. Domains in such a wire are typically 500 mils long and the permanent magnets are conveniently 1500 mils to cooperate therewith.

If the permanent magnet PM of FIG. 9 is displaced to the left as viewed such that its negative end coincides with, for example, the PY1 conductor rather than the PY2 conductor at bit location BL11, then the conductor PY2 may be omitted. Operation on a random access basis is still provided.

What has been described is considered only illustrative of the principles of this invention. Accordingly, various and numerous other arrangements may be devised by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. A combination comprising a plurality of X conductors, a plurality of Y conductors spaced apart from said X conductors and forming crosspoints therewith, a magnetic element associated with said X conductors at each of said crosspoints, means defining a plurality of magnetic storage locations having both first positions including a reverse magnetized domain and second positions associated with said Y conductors at each of said crosspoints, and means selectively moving said reverse magnetized domain from a first to a second position at a selected crosspoint for attracting the corresponding magnet thus making contact between the associated X and Y conductors.

2. A combination in accordance with claim 1 wherein said memory means comprises a sheet of magnetic material substantially isotropic in the plane of the sheet and having a preferred magnetization direction substantially normal to the plane of the sheet, and said reverse domains are single wall domains.

3. A combination in accordance with claim 1 wherein said memory means comprises a film of anisotropic material, and said reverse domains are single wall domains.

4. A combination in accordance with claim 1 wherein said memory means comprises a plurality of domain wall wires and said reverse domains are bounded by leading and trailing domain walls.

5. A combination in accordance with claim 1 also including first circuit means connected to said X conductors and second circuit means connected to said Y conductors, said contact between selected X and Y conductors providing a unique communication channel between said first and second circuit means.

6. A combination in accordance with claim 2 wherein said means defining a plurality of magnetic storage

locations comprises a plurality of X and Y conductors each including a return path and defining with corresponding portions of said return paths electrically conducting loops for defining bit locations in said sheet, and circuit means selectively applying pulses to said X and Y conductors.

7. A combination in accordance with claim 6 wherein said X and Y conductors are organized in pairs for defining in said sheet bit locations including four of said conducting loops for providing a random access organization wherein said first and second positions are spaced apart by first and second intermediate positions.

8. A combination in accordance with claim 2 wherein said X conductors and said Y conductors are arranged in planes spaced apart by an apertured insulating film.

9. A combination in accordance with claim 4 wherein said means selectively moving said reverse domain comprises means selectively expanding said domain.

## References Cited

## UNITED STATES PATENTS

|   |           |         |             |       |         |
|---|-----------|---------|-------------|-------|---------|
|   | 3,268,840 | 8/1966  | Hjertstrand | ----- | 335—205 |
| 5 | 3,295,114 | 12/1966 | Snyder      | ----- | 340—174 |

## OTHER REFERENCES

Spain, R. J., Controlled Tip Propagation, Part I. Journal of Applied Physics, vol. 37, No. 7, June 1966, pp. 2572—83.

BERNARD KONICK, Primary Examiner

G. M. HOFFMAN, Assistant Examiner

U.S. Cl. X.R.

335—205