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CONDUCTOR FOR A THIN FILM MATRIX EMPLOYING A DRIVING
CORE CONNECTED BY RESISTANCE WIRE
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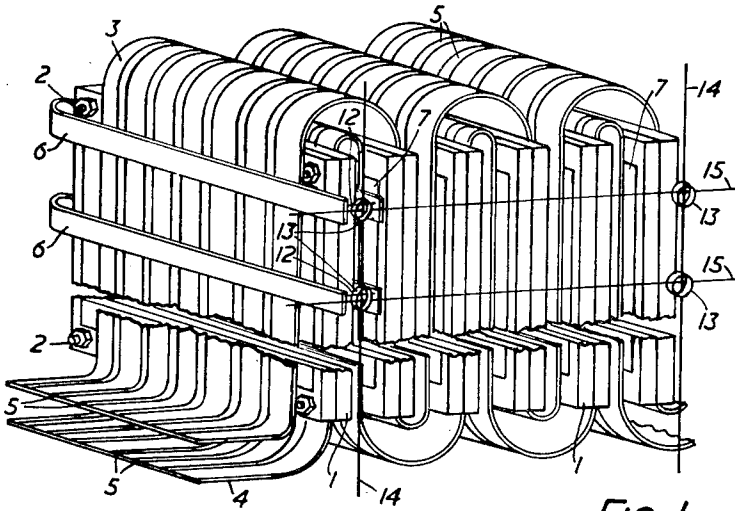


FIG. 1.

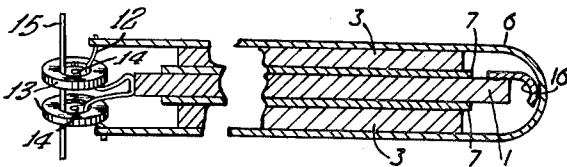


FIG. 2.

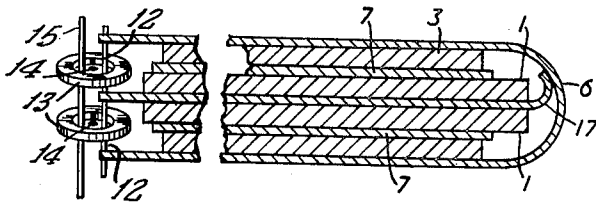


FIG. 3.

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1

2

3,200,383

CONDUCTOR FOR A THIN FILM MATRIX EMPLOYING A DRIVING CORE CONNECTED BY RESISTANCE WIRE

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4 Claims. (Cl. 340—174)

This invention relates to information storage devices employing magnetic storage elements.

It has previously been proposed to provide information storage devices in which an anisotropic thin ferromagnetic film is supported on a substrate and magnetically coupled to driving conductors. The film has an easy direction of magnetisation and is bistable, relaxing in the absence of an applied magnetic field into a stable state in which the magnetisation vector is aligned in one or the other direction along the easy axis. The film is switched from one stable state to the other under the influence of magnetic fields produced by applying driving currents to the conductors coupled to it. Since only the area of film coupled to a conductor is affected by the field produced by the driving current it has been proposed to provide a number of areas of film, on a single substrate. The areas are each separately controlled under the influence of a pattern of conductors applied over the surface of the film. It will be apparent that for each substrate a considerable number of connections are required to select the appropriate film areas to be switched and this problem is aggravated when a number of substrates are used to form a large storage matrix.

It is an object of the invention to provide an improved arrangement of driving conductors for an information storage device employing thin magnetic films.

According to the invention, an information storage device includes a magnetic information storage film, at least one driving conductor forming an elongated open-ended loop, a side of the loop being supported in close proximity to and magnetically coupled to the film, a bistable switch core supported closely adjacent the ends of the loop, a wire joining the ends of the loop linked with the switch core and means for switching the core from one stable state to the other to induce a driving current in the driving conductor.

The switch core may be supported in the space between the open ends of the loop and the loop may embrace the substrate supporting the film. A pair of films may be supported on a substrate structure and there may be a group of further conductors associated with each film of the pair arranged substantially perpendicular to the loop conductor. The substrate may include a conductive return path connected to the mid-point of the loop and in this case the group of further conductors may be common to both films of a pair.

A number of films may be employed requiring a number of loop conductors and the switch cores associated with these loops may be arranged in matrix formation.

Apparatus embodying the invention will now be described, by way of example, with reference to the accompanying drawing, in which

FIGURE 1 shows a perspective view of a thin film matrix, and

FIGURES 2 and 3 show partial sectional views of a return path arrangement for a loop conductor.

The information storage matrix shown has six pairs of substrates plates 1, the plates of a pair being secured together by bolts 2. The major part of the outer face

of each plate is covered by a thin magnetic storage film 7.

A composite conductor carrier 3 passes in serpentine fashion between the pairs of plates 1, so that it is closely adjacent and magnetically coupled to the film on one plate of each pair. A second carrier 4 follows a corresponding path, so that it is closely adjacent and magnetically coupled to the film on the other plate of each pair.

The composite carriers 3 and 4 are identically constructed and their construction is shown and described in detail in co-pending United States patent application Serial No. 136,461, filed September 7, 1961. The inner part of the carrier which is in contact with the film 7 consists of a thin sheet or film of synthetic plastic. The outer surface of this plastic sheet carries a group of parallel sense conductors. A second plastic sheet covers this group of conductors and this second sheet carries a further group of drive conductors. Each of the drive conductors in the second group is superimposed over a corresponding one of the sense conductors, and these conductors occupy the positions indicated by the reference 5.

In the following description the conductors in these groups will be referred to as digit sense conductors and digit drive conductors respectively, following the convention that the matrix is arranged to store information arranged in words, each consisting of a number of digits expressed in binary notation. In order to select a position in which a word may be stored or read out, therefore, additional word drive conductors 6 are provided substantially perpendicular to the conductors in the carriers.

Each pair of plates 1 has associated therewith a number of word drive conductors 6, only two conductors 6 being shown for the sake of clarity. Each conductor 6 is in the form of an elongated open ended loop, with the long sides of the loop positioned close to the outer surface of the carriers 3 and 4. The conductors 6 are insulated from the conductors on the carriers but since the carriers are, in practice, very thin, the sides of the loop conductors lie in close proximity to the film and are magnetically coupled thereto.

The two open ends of the loop are joined by a wire 12 which forms a single turn winding linked with a bistable magnetic switch core 13 which consists of a ring of ferromagnetic material having a substantially square hysteresis characteristic. For the sake of clarity two switch cores 13 are shown coupled in this manner to the conductor 6 and a further pair of switch cores are shown without the coupling to conductors 6. It will be appreciated, however, that a larger number of conductors 6 are provided in association with each pair of plates 1 and that each conductor 6 is associated with a separate switch core 13.

A column selecting winding comprising a conductor 14 threads all those switch cores 13 associated with each of the pairs of plates 1 and a row selecting winding comprising a conductor 15 threads each horizontal row of the cores 13. It will be appreciated that although only two column conductors 14 and two row conductors 15 are shown there will be as many column conductors as there are pairs of plates and as many row conductors as there are word drive conductors 6 on each plate, corresponding word conductors on all the pairs of plates being coupled to switch cores 13 in a common row.

The operation of the matrix in entering and reading out information will now be briefly described. A word is entered by the energisation of a selected word conductor 6 concurrently with the energisation of the digit drive conductors in the appropriate carriers 3 or 4. For

3

example, in a known mode of operation, the energising current is applied in a first direction to the word conductor 6 to provide a resultant magnetic field in one direction to the underlying area of film and the currents applied to the digit drive conductors are in a forward or reverse direction in dependence upon whether the digit to be stored is a binary one or a binary zero. An example of a thin ferromagnetic film store operated in this mode is described in United States patent application Serial No. 779,310, filed December 10, 1958, and now abandoned. The digit representing currents then provide a modifying field to these areas of the film at the intersection of each digit drive conductor with the word drive conductor so that after the drive currents are removed these areas are set to represent the binary digits to be stored. Thus, all the digits of a word are entered into the storage matrix in parallel.

In order to read out the stored word a current in the opposite direction is applied to the word conductor 6 associated with the particular word to be read out. The resultant field applied to the film then causes rotation of the magnetisation vector of a digit-representing area of film, the direction or manner of rotation being dependent upon the digit which was last stored therein. This rotation then induces a signal into the digit sense conductor in the appropriate carrier 3 or 4 associated with this digit storage area. Since the form of these induced signals is dependent upon the manner of rotation of the magnetisation vector, the induced signals provide an indication of the information which was stored in the selected word position.

It will be appreciated that other modes of switching and interrogation of the digit storage areas may be employed to enter and to read out information. For example, the reading out of information may be accomplished by always resetting the digit areas to the binary zero state upon reading out, entry of information requiring simply the switching of those areas in which a binary one is to be stored, so that only these areas which have switched from the binary one state to the binary zero state produce an output signal on reading. However, this mode of operation also requires the application of a driving field to the entire word area in one sense for entry and the opposite sense for reading out of information and the required driving fields are obtained in a similar way by selecting a word drive conductor 6 for the application of a current in one direction for entry and in the opposite direction for reading.

It will be seen, therefore, that the selection of a word position in the matrix for entry or for reading out is controlled by the selection of the appropriate word conductor 6. The conductor 6 is selected by selecting that switch core 13 with which the conductor is associated and this core is, in turn, selected by means of currents applied to the row conductor 15 and the column conductor 14 in conventional manner. For example, the core is switched from a first state to the opposite state during entry of a word into store, the coupling wire 12 linking the core 13 to the conductor 6 such that current is induced into the conductor 6 in the required direction. In order to read out the stored word, the core 13 is switched back to the first state and the current induced in the conductor 6 is then in the opposite direction.

The array of word selecting cores 13 may be considered as a two-dimensional magnetic core matrix, any required core being selected by the application of currents in conventional manner to row and column conductors 14 and 15. It will be appreciated that any suitable mode of operation of such a core matrix may be used to select the required word core. For example, the required core 13 may be switched simply by the application of coincident currents to the particular conductors 14 and 15 which intersect at the core. In another mode of operation all the cores of the array may be biased by a current applied to a common winding, the selecting currents being

4

applied in addition thereto. The particular state to which a selected core is switched is determined by the direction in which the selecting currents flow in the conductors 14 and 15 and it will be apparent that these conductors are each connected to a suitable selecting arrangement.

It will be appreciated that, in dependence on the mode of operation of the film storage matrix, the resetting current for the switching cores 13 may in some cases be required to be larger than the setting current. This effect may be achieved by modifying the rate at which a switch core is allowed to switch in one direction or the other by means of the arrangements for selecting the required conductors 14 and 15.

As explained in co-pending United States application Serial No. 136,461 referred to above, it is desirable that the inductance of the conductors associated with a storage matrix of the kind herein described should be kept to a low value. In a practical matrix, each substrate plate may be a square of approximately 4" side and a film on such a plate can conveniently provide storage for fifty words each consisting of say thirty binary digits. Thus, there are fifty word drive conductors 6 associated with each plate. In order to keep the inductance of these conductors to a minimum it is required to make them as short as possible. As shown in the FIGURE 1 this is achieved by supporting the switch core 13 in the open ends of the loop of the conductor 6 with which it is associated, the length of a conductor 6 in the practical matrix described above then being of the order of 20 cm.

The switch cores 13 may be supported, as shown, by the conductors linking therewith or they may be held by a suitable support closely adjacent to the matrix plates. Where the storage device is operated at a high speed it is preferred to mount the switch cores on a support plate having good heat and electrical conductive properties. This support plate is preferably copper or aluminium although it will be appreciated that other materials are suitable. The effect of this plate under these conditions is that heat generated by the switching of a word selecting core 13 where, for example, one word is repeatedly selected is rapidly conducted away from the core and the inductance of the word selecting loop including the wire 12 and also of the selecting conductors 14 and 15 is kept to a low value.

In order to maintain the inductive time constant of the entire word selecting loop including the conductor 6 and the wire 12 at a low value under these high speed conditions it is also preferred to use resistance wire for the wire 12.

It will be appreciated that in the form of construction shown the films of each pair with which the conductor 6 is linked are individually supported on substrate plates 1 mounted back to back and there is sufficient space between the open ends of a parallel-sided loop to accommodate a suitable switch core. However, the thickness of the plates may be such that it is not possible to position a core of the required dimensions in the space between the ends of the loop if the sides of the loop are made parallel throughout their length. In this case the ends of the conductor 6 may be splayed slightly to provide the necessary space. Alternatively the conductors 6 may be slightly shortened to project only sufficiently far beyond the end of the plate 1 to allow the wire 12 to be connected. The switch core 13 is then mounted as closely as possible to the end of the conductor 6 so that the length of the wire 12 is kept to a minimum.

The United States patent application Serial No. 136,461 referred to above describes the use of a single substrate to support a pair of films, one on each face, to replace the back-to-back pair of substrates shown in FIGURE 1, and also describes the use of a single conductor carrier, such as the carrier 3, coupled to both films of a pair. It will be realised that the use of a single carrier in this way in conjunction with a single loop conductor

5

6 would result in two word positions being used to store identical data. However, each long side of the loop may be used independently by providing a common return path from the mid-point of the loop and driving each half-loop by a separate switch core. Both switch cores are linked by the wire 12 joining the ends of the loop but, again, the mid-point of the wire 12 is joined to the common return path. Alternatively, each core may be linked with a separate wire connecting the common return to the appropriate loop end.

The substrate 1 supporting the films may be conductive and then provide the return path. FIGURE 2 shows a single conductive substrate 1 carrying a pair of films 7. A conductor carrier 3 is provided, common to both films of the pair and the word driving conductor loop 6 is provided embracing the carrier 3. A connection 16 is provided between the mid-point of the loop and the conductive substrate 1. The same effect may be obtained where a non-conductive substrate is used by coating one or both sides of the substrates with a conductive layer and connecting the layer to the connection 16.

It will be appreciated that a pair of back-to-back conductive substrates may be connected to the mid-point of the loop in the same way. An alternative method of providing a common return path in the case where a pair of non-conductive substrates, such as glass for example, are used in a back-to-back paired arrangement is shown in FIGURE 3. In this case the substrates 1 each carry a film 7 as before, and a conductor carrier 3 and word drive conductor 6 are coupled to the films 7. In this case, however a foil layer 17 is sandwiched between the substrates and is connected to the midpoint of the loop 6. The return path, either the conductive substrate 1 or the foil 17 is, in the cases described above, preferably provided with connecting lugs to facilitate connection with the mid-points of the loops and also to the wires 12. Thus, in these cases it will be seen that each half of the loop 6 is selected independently of the other by a separate switch core.

I claim:

1. An information storage device including a thin magnetic information storage film supported on a substrate; a driving conductor forming an elongated open ended loop, the substrate positioned within the loop and one long side of the loop being closely spaced from the magnetic film and magnetically coupled therewith; and means for inducing a driving current in the loop comprising a bistable magnetic switch core supported closely adjacent the open ends of the loop; a coupling between the loop and the switch core consisting of a resistance wire joining the open ends of the loop and threading the switch core; and at least one other conductor threading the switch core to drive it from one to the other of its stable states.

2. An information storage device including a thin magnetic information storage film supported on a substrate; a first group of driving conductors closely spaced from the film and magnetically coupled therewith arranged in parallel spaced apart formation in one direction across the substrate; a second group of driving conductors arranged substantially at right angles to said first group, each driving conductor of said second group being formed as an open ended loop embracing the substrate, one long side of the loop being closely spaced from the film and magnetically coupled therewith; a separate bistable switch core for each conductor of said second group supported between the open ends of the loop; a length of resistance wire threading the switch core and connected between the ends of the loop; and means including core selecting

6

conductors threading the switch cores for switching a selected core from one to the other of its stable states to induce a driving current into that conductor of the second group coupled by said resistance wire to the selected core.

3. An information storage device including, a pair of thin magnetic information storage films respectively supported on the outward facing surfaces of a pair of back-to-back planar substrates; an electrically conductive layer sandwiched between said substrates; a first group of driving conductors supported to pass about the substrates in parallel formation in a first direction across said storage films and in close proximity thereto to link magnetically with the films; a second group of conductors each formed as an elongated open-ended loop having substantially parallel sides said loop being arranged about the substrates to pass across the films in a second direction substantially perpendicular to the first conductors, the elongated sides of the loop being respectively positioned each in close proximity to a film of the pair and magnetically coupled therewith; an electrical connection between the mid-point of the loop and the conductive layer; a pair of bistable switch cores for each conductor of said second group supported adjacent the open ends of the loop; a pair of connections respectively connecting an end of the loop with said conductive layer and threading a corresponding switch core of the pair; and means including core selecting conductors threading the switch cores for switching a selected core from one to the other of its stable states to induce a driving current into that side of a conductor of the second group coupled to the selected core by the threaded connection.

4. An information storage device including, a pair of thin magnetic information storage films respectively supported on the opposite outwardly-facing surfaces of a plate-like electrically conductive supporting structure; a first group of driving conductors supported about the structure to pass in parallel formation in one direction across both storage films and in close proximity thereto to couple magnetically with the films; a second group of conductors each formed as an elongated open-ended loop having substantially parallel sides, the loop being arranged about the structure to pass across the films in a direction substantially perpendicular to said one direction, the sides of the loop being respectively positioned each in close proximity to a film of the pair and magnetically coupled therewith; an electrical connection between the mid-point of the loop and the conductive structure; a pair of bistable switch cores supported adjacent the open end of the loop; resistance wire connections between the ends of the loop and the conductive structure, each of the connections respectively threading a corresponding switch core of the pair; and means including core selecting conductors threading the switch cores for switching a selected core from one to the other of its stable states to induce a driving current into that side of a conductor of the second group coupled to the selected core by the threaded connections.

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IRVING L. SRAGOW, *Primary Examiner.*