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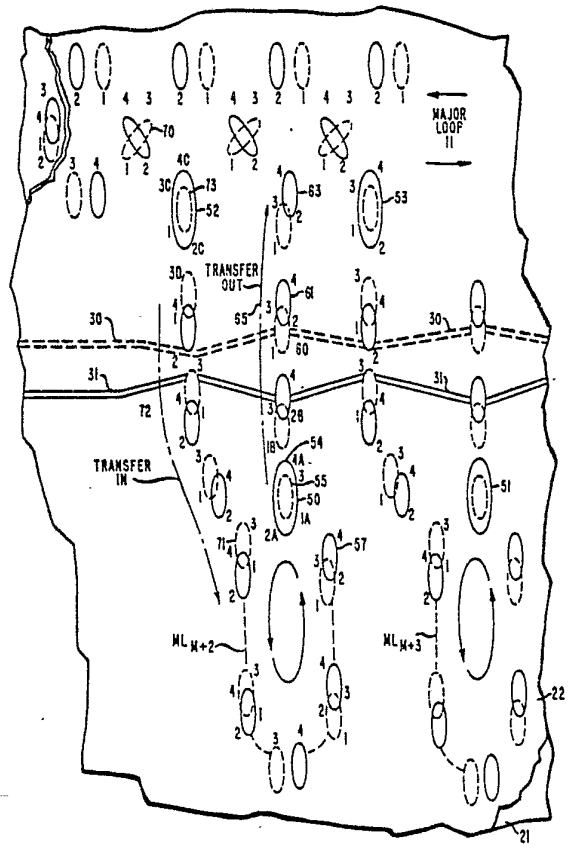
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(57) Abstract

A conductor access, magnetic bubble memory is organized in a major-minor mode by including transfer locations (52, 54) in the conducting layers (21, 22) which define the normal bubble propagation implementation. A partitioning (30, 31) of each of the two conducting layers permits the minor loops and the major loop to be operated synchronously or independently resulting in short duty cycles which permit low power operation to be achieved.



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CONDUCTOR ACCESS MAGNETIC BUBBLE MEMORY ARRANGEMENT

Field of the Invention

This invention relates to magnetic bubble memories, and more particularly to such memories characterized by transfer gate implementations whereby bubbles are moved from one propagation path to another.

Background of the Invention

Magnetic bubble memories as well as the "major-minor" organization of such memories are well known in the art as is disclosed in U. S. Patent No. 3,618,054 of P. I. Bonyhard, U. F. Gianola, and A. J. Perneski, issued November 2, 1971.

The major-minor organization is characterized by a set of closed "minor" loops in which bubble patterns are recirculated synchronously in response to a magnetic field reorienting cyclically in the plane of bubble movement. The bubbles in each loop are moved through a transfer position which couples a minor loop to a stage of an accessing loop called the major loop. An electrical conductor couples all the transfer positions and is operative, when pulsed, to transfer the bubble pattern, occupying all the transfer positions, into the major loop for movement to a detector. The transfer operation from a minor loop to a major loop is commonly referred to as a "transfer out" operation and results in vacancies in those positions in the minor loops from which the transferred bubble pattern originated.

A bubble generator, on the other hand, provides a bubble pattern for movement into those vacancies. The generator is coupled to the major loop and is operative, responsive to a sequence of input signals, to enter a replacement bubble pattern into the major loop. The major loop also is responsive to the cyclical field to move bubbles. Consequently, an input signal during each cycle of the field results in a bubble pattern moving in the

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major loop towards the transfer positions as the vacancies in the minor loops move towards the transfer positions. An appropriately timed transfer operation moves the replacement bubble pattern into the vacancies. The major-minor organization is useful primarily to decrease the latency time and the access time of "field access" type bubble memories which are characterized by a reorienting "in plane" field as described hereinbefore.

Another type of magnetic bubble memory employs electrical conductors rather than a reorienting in-plane field to effect bubble propagation. In the past, conductor access type bubble memories included discrete electrical conductors which could be pulsed selectively to produce bubble movement. There was no need for the major-minor organization in this type of memory. In a recent development (disclosed in PCT application 79/00386) utilizing two mutually insulated conductive layers each containing a pattern of apertures which define the paths for movement of the bubbles, no discrete conductors exist; yet a major-minor organization is particularly attractive. Consequently, a transfer gate is necessary, but no discrete conductors are present to implement a transfer gate. The problem, then, to which the present invention is directed is to provide a transfer gate compatible with the aforedescribed recently developed devices without employing any additional electrical conductors.

Brief Description of the Invention

A compatible transfer gate is realized in a conductor access arrangement of the aforedescribed recently developed type by forming, for example, concentric apertures in the two electrically conducting layers. For propagation, currents are impressed in the two conducting layers (separated by an electrically insulating layer) alternately first in one direction, then in the opposite direction. The layers have offset apertures operative to produce changing field gradients

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to move bubbles. By forming concentric apertures at transfer positions, rather than offset apertures, an alternative sequence of pulses causes bubbles in transfer positions to move to different paths while the bubbles not in transfer positions are moved in only a negligible manner consistent with the preservation of data when propagation continues.

Brief Description of the Drawing

FIG. 1 is a schematic representation of a magnetic bubble memory arrangement in accordance with this invention;

FIG. 2 is a top view of portions of the arrangement of FIG. 1; and

FIG. 3 is a pulse diagram of the operation of the memory of FIG. 1.

Detailed Description

FIG. 1 shows a block diagram of a generalized major-minor organized magnet bubble memory 10. The memory includes the usual minor loops ML_1, ML_2 --- ML_M, ML_{M+1} --- ML_N, and a major loop 11. A bubble generator arrangement 12 and a bubble detector arrangement 13 are coupled to the major loop and are connected to an input circuit 15 and to a utilization circuit 16 respectively. A bias field source, not shown, maintains the bubbles at a nominal diameter in well known manner.

Operation of a major-minor bubble memory requires transfer or replication of bubble patterns, for example, from the minor loops to the major loop for detection. We are interested herein primarily with a transfer operation in the context of a conductor access bubble propagation arrangement. Consequently, a brief discussion of a conductor access arrangement is appropriate for a full understanding of the transfer operation.

Bubble movement takes place in a host layer 20 in response to currents impressed in electrically conducting layers 21 and 22. The layers are insulated from one another and include apertures which are so disposed that

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current pulses alternately in layers 21 and 22 and in an appropriate sequence of directions causes movement along the paths represented by the loops in FIG. 1. The overall bubble propagation operation is disclosed in the afore-mentioned PCT application. In general, the apertures are shaped and disposed so that an otherwise uniform current flow in layers 21 or 22 is modified locally at each aperture to generate a localized magnetic field gradient to move a bubble. The apertures are disposed so that successive current pulses cause a changing pattern of localized field gradients which move a bubble pattern along the paths indicated in FIG. 1.

A transfer function is implemented by a different relationship between the apertures in layers 21 and 22 at locations in which a transfer operation is to occur. The operation itself results from a change in the normal propagation pulse sequence as is now discussed in connection with FIG. 2.

FIG. 2 shows an enlargement, rotated 90^{o}, of area 30 of the memory of FIG. 1. The figure shows specifically the features of layers 21 and 22. The features of layer 21 are represented by broken lines to indicate that layer 21 is beneath layer 22. The features of layer 22 are represented by unbroken lines. An insulating layer separates layers 21 and 22, hence the features of layer 21 are shown broken even though exposed by associated apertures in top layer 22.

The area 30 shown includes two minor loops ML_{M+2} and ML_{M+3}, a major loop 11, and various patterns of apertures extending between each minor loop and the major loop to effect transfer of bubbles therebetween. This is described hereinafter. Also, as shown, left to right extending slots 30 and 31 are formed in layers 21 and 22, respectively, to allow currents to be impressed independently in each of the area of the minor loops and in the area of the major loop. A partitioning of layers 21 and 22 in this manner

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allows a short duty cycle to be realized and thus permits low power levels to be realized. This is further described hereinafter.

The movement of bubbles in response to a pulse train in layers 21 and 22 occurs along the sequence of positions designated 1-2-3-4- to correspond to a propagation pulse sequence represented in FIG. 3 by the pulse forms P21 and P22. Bubble movement can be seen in FIG. 2, to occur, for example, in a counterclockwise direction about minor loop ML_{M+2} as indicated by the curved arrows there. Until a transfer operation occurs, the various bubbles within the minor loop ML_{M+2}, as well as those within the other minor loops, continue to circulate thereabout, as generally known. Similarly, bubble movement is in a counterclockwise direction around major loop 11. Remember that the pulse sequence shown can be impressed independently in the subportions of layers 21 and 22, and thus bubble movement can occur in the minor loops or the major loop or both. Means for providing various sequences of current pulses are known. A suitable drive is represented by block 40 in FIG. 1. The provision of the pulses selectively is controlled by a control circuit also operative to interrogate the detector arrangement and to synchronize the propagation and transfer circuits in a manner now well understood in the art. A control circuit is represented by block 41 in FIG. 1.

Now we will direct our attention to the transfer operation in the context of a conductor access, bubble memory as shown in FIG. 2 having partitioned electrically conducting layers. The transfer operation is caused by the presence of associated apertures in layers 21 and 22 which apertures are illustratively concentric and of smaller and larger dimensions respectively. Such an arrangement of apertures is represented at each of locations 50, 51, 52, and 53 in FIG. 2.

Consider location 50 at the top of minor

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loop ML_{M+2}. For an 8 micron period circuit, aperture 54 has dimensions of 8 x 2.5 microns and aperture 55 has dimensions of 4 x 2 microns. A bubble for such a circuit has a nominal diameter of 1.6 microns. A bubble in loop ML_{M+2} approaches aperture 57, moving to position 4 thereof in normal sequence when a pulse sequence modification occurs for a transfer out-operation. The modified pulse sequence is 1A-2A-1A-4A-1B-2B, the letter designations being shown in FIG. 2. The normal sequence thereafter carries a transferred bubble to positions 1-2-3-4- associated with aperture 60 and 61.

Stated differently, if the normal sequence of current pulses continued after a bubble reached position 4 of aperture 57, the bubble would have followed the path 1A, 2A (aperture 50), 3, 4 (aperture 71) and remained within the minor loop ML_{M+2}. By modifying the pulse sequence, however, the bubble leaves the minor loop and sets off along the path identified by arrow 65. Once the bubble is diverted by means of the modified pulse sequence, the normal pulse sequence continues it along its new path.

Note that the so-transferred bubble passes slots 31 and 30 in sequence during the transfer operation. Therefore, both portions of layers 21 and layers 22 necessarily are pulsed electrically in parallel to effect the above transfer. An additional cycle of operation moves the bubble to position 4 of aperture 63, a position which lies in the major loop along which the bubble moves to the right in response to later cycles of operation. The transfer-out operation is now complete.

Of course, a bubble (or no bubble) is similarly moved, in parallel, from each like position in another of the minor loops as can be appreciated by comparing the geometry of location 51 with that of 50. Consequently, major loop 11 ultimately includes a bubble pattern from the bit location in the minor loops corresponding to those which occupy the transfer locations when a transfer

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operation occurs.

Propagation currents need be applied thereafter only to those portions of layers 21 and 22 which are associated with the major loop. In this manner data may be moved to the detector and back to the transfer locations while data in the minor loops remain unmoved. The requisite amount of power required for operation is thus reduced.

In accordance with the embodiment of FIG. 2, data, once detected at 13 of FIG. 1, is moved back to the transfer location for transfer into the originating bit locations which are positioned to accept the data. Known techniques are used to synchronize the movement of the incoming data and the vacancies in the minor loops so that the pattern of incoming bubbles is correctly inserted into the vacancies in the minor loops.

When that data generated at 12 moves to positions 4c at, for example, apertures 52 and 53, a transfer-in operation commences. The transfer-in operation is explained in connection with a bubble initially at position 1 at aperture 70 in major loop 11. The destination of the bubble is position 3 at aperture 71 in minor loop ML_{M+2} in FIG. 2. The path of bubble movement during the transfer in operation is identified by arrow 72 in FIG. 2.

The transfer-in pulse sequence, applied to all portions of layers 21 and 22, is 1-2-3c-4c- 3c-2c-3d-4-1-2, where 2c is at aperture 52. Position 3c is associated with aperture 73 (in layer 21). Position 2c is associated with aperture 52 (in layer 22). Further normal pulse sequences result in movement of the bubble to its desired destination. As described above, bubbles in like positions in the major loop (see aperture 53) similarly move to their respective minor loop destinations. The operation is now complete.

Control circuit 41 may now impress a pulse sequence in the portions of layers 21 and 22

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associated with the minor loops to move a next selected address to the transfer locations. The pulses required for transfer are impressed simultaneously in both portions of each of layers 21 and 22, but merely shuttle bubbles in positions outside the transfer locations in a negligible manner. These pulses are applied to a transfer conductor 78 (FIG. 1) by a transfer circuit represented by block 79. Once the data is in the major loop, data in the minor loops may remain unmoved as mentioned hereinbefore.

The transfer-in operation occurs not only after data has been detected but also when new data is being written. Input circuit 15 is adapted to generate a bubble pattern in the major loop in conventional fashion under the control of control circuit 41 by applying appropriate current pulses to a conductor 80 of FIG. 1 during desired cycles of operation for forming a data stream. Conductor 80 conveniently is adapted to couple other stages of the major loop to annihilate detected data which newly written data is intended to replace. Alternatively, separate annihilate conductor and pulse sources may be used.

FIG. 3 shows the first, second, and third pulse sequences for, respectively, normal bubble propagation, transfer-out, and transfer-in. The broken pulse forms are designated P21 and are impressed in layer 21 of the illustrative embodiment. The solid pulse forms represent the currents impressed in layer 22. The pulse sequence of 1-2-3-4 can be seen to correspond with the notations in FIG. 2 for normal bubble movement. The second sequence of 1-4-1-2 can be seen to correspond to the crucial portion of the transfer-out operation as can the sequence of -3-2-3-4 be seen to correspond to the crucial portion of the transfer-in operation. Circuitry operative to apply the proper pulse sequences is straightforward and is included in control circuit 41 for controlling driver 40 of FIG. 1. The circuits may be any

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such circuits capable of operating in accordance with this invention. As may be observed from the designation in FIG. 2, the second and third pulse sequences only negligibly shuttle nontransferred data between positions from which normal bubble propagation continues at the conclusion of the transfer operation.

An ion-implanted layer usually is included in the bubble layer 20 to suppress hard bubbles as is in common use in the art. With the dual-conductor technology, it is advantageous to form the ion-implanted layer at the lower surface of bubble host layer 20 next to the substrate on which layer 20 is formed. Such a subterranean ion-implanted layer suppresses hard bubbles but does not act to reduce the coupling between the conductor layers and the bubbles.

Although FIG. 1 shows the memory chip as being essentially square, consideration of preferred impedance characteristics dictates a rectangular geometry for the chip. Of course, the conductor layers can be formed to provide a folded geometry for the current paths to achieve a relatively square chip while retaining attractive impedance characteristics.

The illustrative embodiment calls for a shuttling of the transferred bubbles during the transfer operation as is clear from an examination of the transfer-in and transfer-out pulse sequence. The shuttling is not necessary but has been found to enable improved operating margins to be obtained. Also, the invention has been described in terms of apertures through each of layers 21 and 22. The apertures cause localized impedance changes in the conducting layers and such changes can be achieved in alternative ways. For example, the apertures may be openings entirely through the conducting layers, or just indentations in the layers causing a reduction in the cross-sectional area at the indentions, or the conducting layers may be oxidized locally, the non-conducting oxide portions forming and filling the

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apertures. The word "aperture" is thus generic to all three embodiments.

Moreover, the transfer location, as shown, comprises nested apertures which illustratively are concentric. The apertures need not be concentric. They need only be of a shape and disposed with respect to one another to allow field gradients to be generated along first and second paths in response to first and second pulse sequences respectively.

The illustrative embodiment includes a set of minor loops to each side of the major loop in a symmetrical arrangement. Such a symmetrical arrangement results in balanced fields, at major loop 11, associated with the current drives and acts to reduce any field imbalance which would produce a vector normal to layer 20.

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Claims

1. A magnetic bubble memory comprising a host layer (20) of material in which magnetic bubbles can be moved along at least first and second multistage paths, said paths being defined by first and second patterns of associated apertures in first (21) and second (22) layers of electrically conducting material adjacent said host layer, associated ones of said apertures in said first and second layers being offset from one another in a manner to generate changing patterns of magnetic field gradients for moving bubbles along said paths synchronously in response to a first pulse sequence (1, 2, 3, 4) applied to said first and second layers,

CHARACTERIZED BY

a transfer location (50, 55) adapted for moving bubbles from said first to said second path, apertures (50, 55) in said first and second layers at said transfer location having geometries and being disposed with respect to one another to generate magnetic field gradients along said first path and from said first to said second path in response to first and second (1, 4, 1,2) pulse sequences respectively.

2. A magnetic bubble memory in accordance with claim 1

CHARACTERIZED IN THAT

said apertures at said transfer location are relatively small and relatively large in said first and second layers respectively, said relatively small aperture being encompassed by said relatively large aperture.

3. A magnetic bubble memory in accordance with claim 2

CHARACTERIZED IN THAT

said first and second paths are closed loop paths.

4. A magnetic bubble memory in accordance with claim 2 including a plurality of said first paths

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said first paths are all closed loops and a transfer location is associated with each of said first paths.

5. A magnetic bubble memory in accordance with claim 4 wherein said second path also comprises a closed loop

CHARACTERIZED IN THAT

a second transfer location is associated with each of said first transfer locations, and means for selectively moving bubbles at said first and second transfer locations from said first paths to different stages of said second path and from different stages of said second path to different ones of said first paths responsive to second and third pulse sequences respectively.

6. A magnetic bubble memory in accordance with claim 5

CHARACTERIZED IN THAT

each of said first and second layers is partitioned into first and second portions corresponding to said first paths and to said second path respectively, and means for applying said first, second, and third pulse sequences to said first portions of said first and second layers and to said second portions of said first and second layers selectively.

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FIG. 1

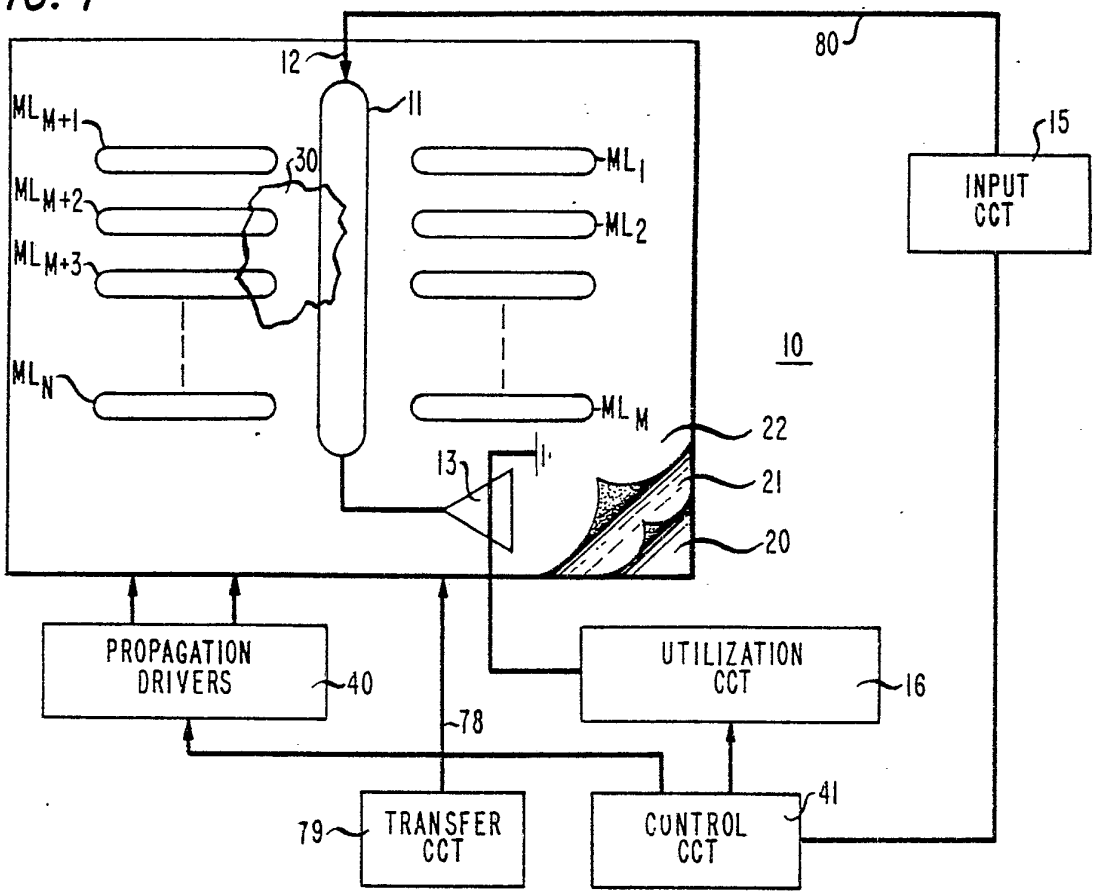
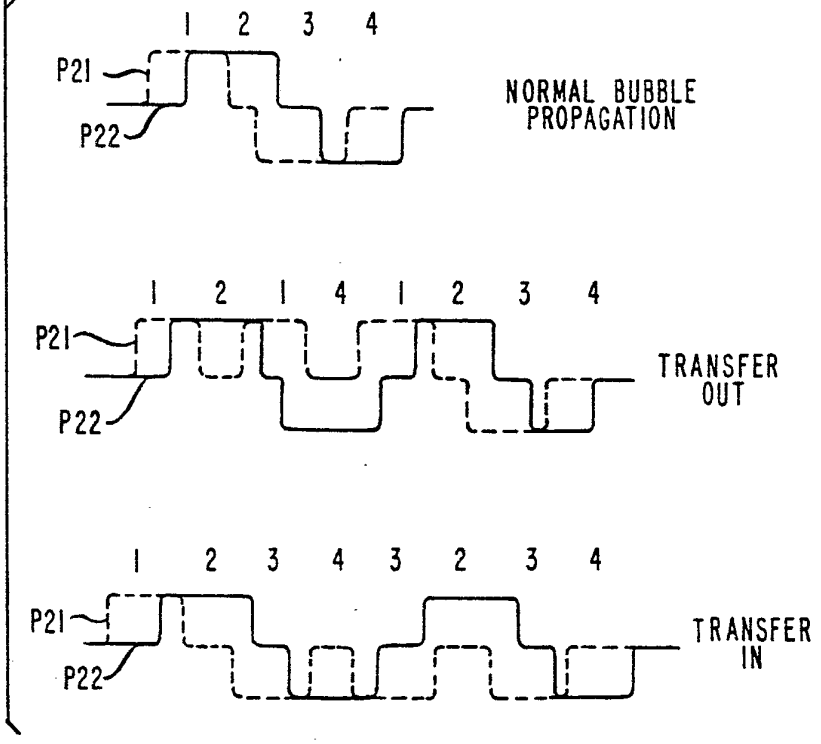
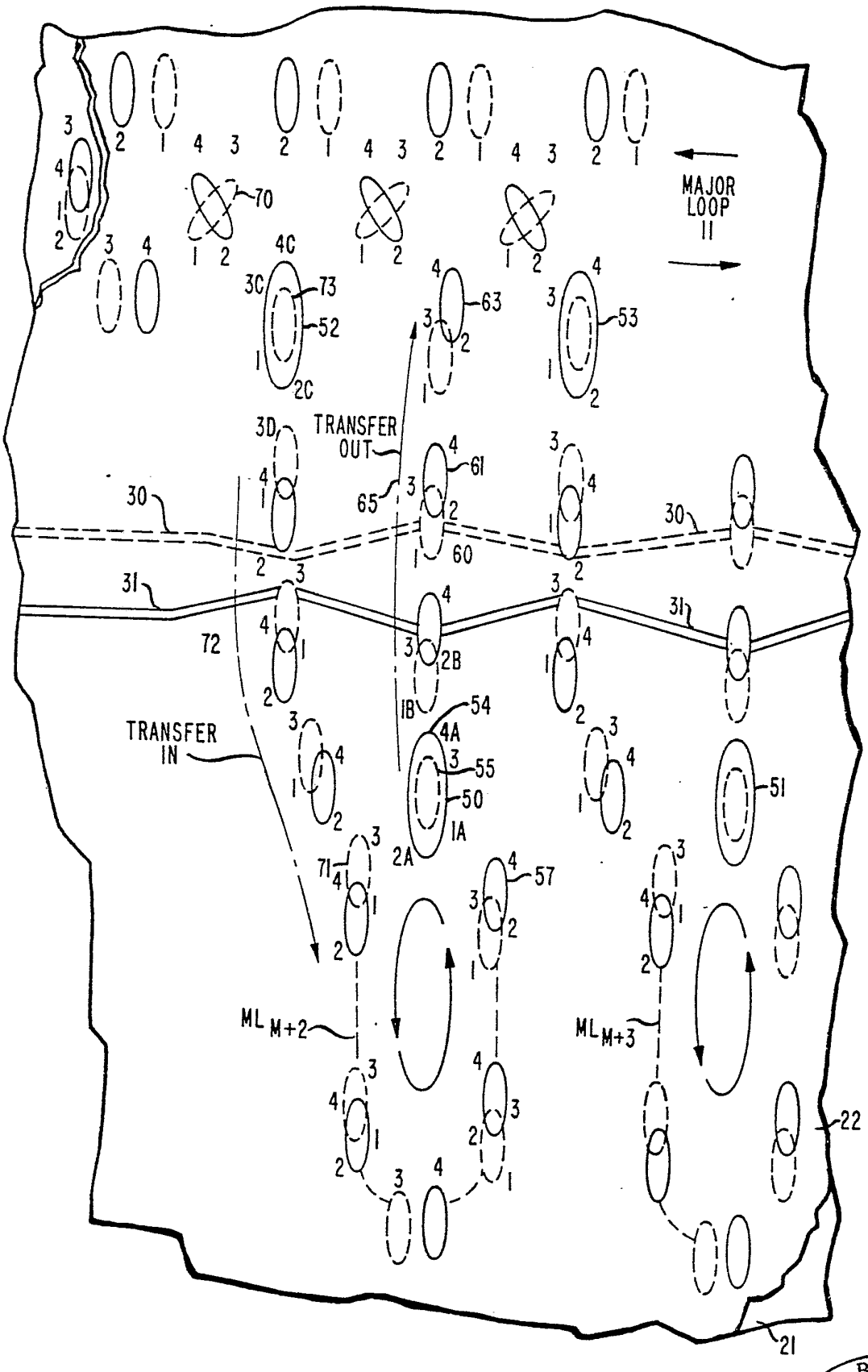


FIG. 3



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FIG. 2



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INTERNATIONAL SEARCH REPORT

International Application No PCT/US80/00169

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

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II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
P	US, A, 4,143,419, Published 06 March 1979 Bobeck.	1-6
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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
10 April 1979	12 MAY 1980
International Searching Authority [1]	**Signature of Authorized Officer [20]**
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