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HIGH SPEED MAGNETORESISTIVE SWITCHING DEVICE
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FIG. 1

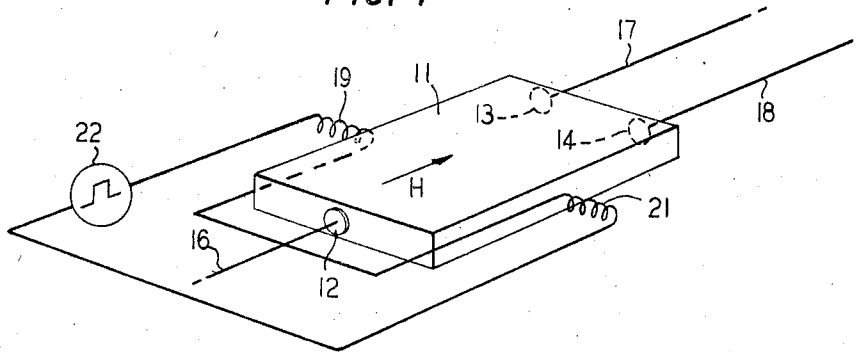


FIG. 2

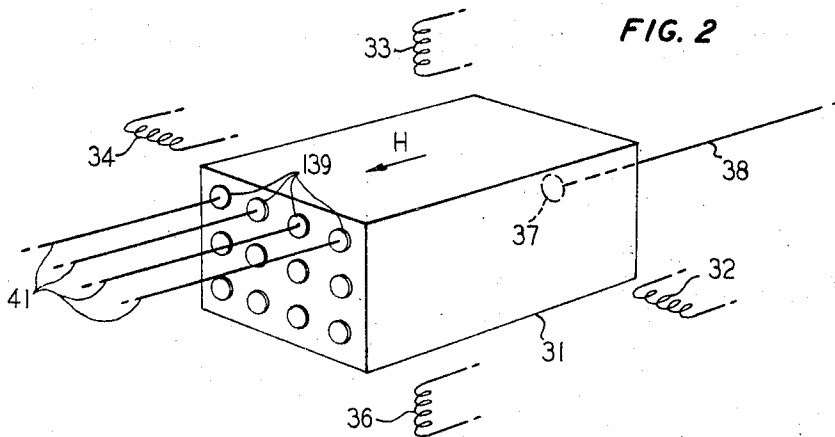
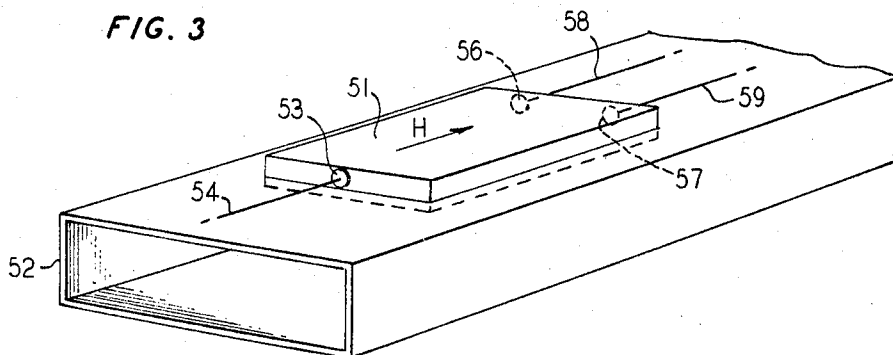


FIG. 3



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HIGH SPEED MAGNETORESISTIVE SWITCHING DEVICE

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8 Claims

This invention relates to electronic devices, and, more particularly, to magnetically controlled high frequency electronic switching devices.

In the fields of logic systems, display arrangements, and communications, high speed switches are essential elements in the overall systems. It is desirable that such switches have, in addition to their high speed capabilities, reliability, compactness, simplicity, and long life. Generally speaking, it is difficult to realize all of these desiderata in the various types of switches available. Mechanical switches not only have speed restrictions because of the inertia of moving parts, but also tend to be short lived, relatively speaking, because of contact erosion and wear. Electron beam type arrangements are bulky and complex. Semiconductor devices have been made to function well as switches, but have a tendency to be unreliable due to variations in operating parameters among several such devices, necessitating some sort of compensation arrangement to insure uniformity of behavior.

The present invention, which achieves the desired ends of high speed operation, reliability, simplicity, and long life, is based upon the behavior of charge carriers in certain semimetal or semiconductor materials under the influence of a magnetic field. In such a material, when a voltage is applied across it, there is a plasma flow, made up of the movement of both electrons and holes in the material. In such materials having a high transverse magnetoresistance to longitudinal magnetoresistance ratio, the charge flow is constrained to follow the direction of magnetic flux in the material, hence the application of a magnetic field to the material determines the direction of the charge flow.

In a first illustrative embodiment of the invention, a slab of bismuth or other suitable semimetal or semiconductor has a single first conductive contact on one end, and a pair of conductive contacts on the other end. The contacts are connected into a circuit in the manner of a switch. A longitudinal magnetic field is applied to the material by suitable means such as a permanent magnet so that the magnetic flux extends from one end of the slab to the other. A pair of switching coils are disposed adjacent to the slab and are supplied with switching signals from a suitable source. Application of a signal to the coils produces a transverse magnetic field in the slab which, added to the steady state field, produces a resultant field that can be made to lie in the direction extending from the single contact end of the material toward one or the other of the two contacts on the other end, but not both. As a consequence, current flows parallel to the flux lines to the one contact but not to the other because of the high transverse magneto-resistance. Reversal of the signal to the coils changes the magnetic field direction and the current then flows to the other of the two contacts. We then have the basis for a single pole-double throw switch. Be-

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cause there is virtually no remanent magnetic field in bismuth, for example, switching can be accomplished at a rate determined primarily by the speed with which the magnetic coils reverse the magnetic field. This of course, with properly designed coils, can be done at radio frequencies and even microwave frequencies.

In another illustrative embodiment of the invention a block of semimetal such as bismuth or antimony, or semiconductor such as indium antimonide, is provided with a single conductive input contact on one end, and a multiplicity of contacts on the other end, arrayed, for example, in a rectangular matrix. A permanent magnet or other suitable means supplies a steady state longitudinal magnetic field through the block. Arranged around the block in a manner analogous to the magnetic deflecting coils of a cathode ray tube are a plurality of coils which, upon application of signals from a suitable source, produce magnetic fields in the block which, when added to the steady state magnetic field, define a low resistance charge carrier path between the input contact and any desired address in the matrix array of contacts. Such an arrangement functions as a single pole-multiple throw switch which can be used, for example, to interrogate a memory bank, to supply a scanning roster for a display device, or any of a number of similar uses.

In an embodiment of the invention for use at microwave frequencies, a slab of a semimetal is mounted in one wall of a waveguide, suitably positioned to be in a region of maximum magnetic field of a signal wave propagating through the guide. A magnetic bias is applied to the slab, one end of which has a single input contact and the other end one or more output contacts. In operation the device functions as a high speed single pole-multiple throw switch under the influence of waves propagating in the waveguide.

It is a feature of all of the embodiments of the invention that a member of material having a high ratio of transverse to longitudinal magnetoresistance, i.e., magnetoresistive material, has spaced contacts on its surface and magnetic means for defining a flux path between selected ones of said contacts.

The principles of the present invention will be more readily understood from the following detailed description, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective schematic view of a first illustrative embodiment of the invention;

FIG. 2 is a perspective schematic view of a second illustrative embodiment of the invention; and

FIG. 3 is a perspective schematic view of a third illustrative embodiment of the invention.

FIG. 1 of the drawings shows an embodiment of the invention in which operation as a simple, single pole, double throw switch is achieved. The arrangement of FIG. 1 comprises a slab 11 of bismuth or other suitable material having a single conductive contact 12 at one end thereof and a pair of conductive contacts 13 and 14 at the other end. Current conducting leads 16, 17, and 18 are connected to contacts 12, 13, and 14, respectively. A magnetic field H, supplied by any suitable means which, for simplicity, has not been shown, extends longitudinally through slab member 11, as shown by the arrow. A pair of coils 19 and 21 are located on either side of member 11 and are supplied with current from a suitable source 22.

In operation, leads 16, 17, and 18 are connected into any one of a number of possible circuits where it is desired to switch an input to contact 12 to either contact 13 or contact 14, or inputs to contacts 13 and 14 to contact 12. Source 22, which may take any one of a number of forms as a source of switching signals, supplies switching signals to coils 19 and 21, which are oriented so that their magnetic fields are additive. The magnetic field generated by the coils 19 and 21 extends transversely of member 11 and adds vectorially to the steady state magnetic field H to produce a resultant field which extends between contact 12 and one or the other of contacts 13 and 14.

As was pointed out before, the materials under consideration here have a high ratio of transverse to longitudinal magnetoresistance. By "high" is meant a ratio of 10^2 or better. This ratio varies not only with the type of material but also with the strength of the magnetic field and with temperature, being higher, the lower the temperature. Thus typically, bismuth has a ratio of 10^3 - 10^4 at 1000 gauss, antimony has a ratio of 10^3 at 1000 gauss, and indium-antimonide has a ratio of 10^2 at approximately 10,000 gauss. In general, it is desirable that the magnetic field be as small as possible while a ratio of 10^2 or better is achieved. However, for many possible applications, higher values of magnetic fields may be used, thus increasing the number of materials that may be used. With a ratio of 10^2 or better, current through member 11 follows the flux lines of the magnetic field. The current does not diffuse or spread out because of the transverse magnetoresistance to current flow and also because of the pinching effect of the current generated magnetic field. As a consequence the current flows from contact 12 in a straight line to contact 13, for example. Because of the aforementioned magnetic effects, the cross-sectional area of the current path is governed by the diameters of the contacts. As a consequence, heating effects can be minimized by increasing the size, i.e., diameter, of the contacts.

In the arrangement of FIG. 1, a change in direction of the magnetic field produced by coils 19 and 21 switches the current path so that current flows from contact 12 to contact 14 instead of contact 13. Rapid switching between the contacts can thus be achieved.

In FIG. 2 there is shown an arrangement, the basic operation of which is the same as that shown in FIG. 1, which functions as a single pole-multiple throw switch. The arrangement of FIG. 2 comprises a block 31 of suitable magnetoresistive material such as bismuth which has applied thereto a longitudinal magnetic field H by a suitable source which, for simplicity, has not been shown. Disposed about block 31 are a plurality of coils 32, 33, 34, 36 which are oriented to produce transverse magnetic fields in the block 31. For the particular arrangement of FIG. 2, coils 32, 33, 34, and 36 may be connected to a source of, for example, deflection signals, in which case these coils are analogous to the magnetic deflection coils of a cathode ray tube. Because of this analogy, the particular connections to the coils have not been shown, nor has the source of deflection signals, in the interests of simplicity and clarity. From the following description it can be seen that any of a number of possible arrangements may be used.

At one end of member 31 there is mounted a conductive contact 37 to which is affixed a conductive lead 38. At the other end of member 31 and array of contacts 39 is mounted, and conductive leads 41 are affixed to each of the contacts. In operation, by means of appropriate signals to coils 32, 33, 34, and 36, a current path is established between contact 37 and any one of the contacts 39. The array of contacts 39 may be scanned sequentially in the manner of a cathode ray tube raster, or any one of the contacts 39 may be sampled or energized selectively. With such an arrangement, it is obvious that any one of a number of individual circuits connected to leads 41 may be interrogated or energized, as in the selective interroga-

tion of a memory system, or in the sequential energization of elements of a display device.

In FIG. 3 there is shown an arrangement similar to that of FIG. 1 but in which the magnetic field of microwave signals propagating in a waveguide supplies the transverse component of magnetic field.

The arrangement of FIG. 3 comprises a slab 51 of bismuth or other suitable material which is mounted in an aperture in one wall of a waveguide 52, through which switching signals from a suitable source, not shown, propagate. Preferably the slab 51 is mounted in the wall of the waveguide in a region of maximum magnetic field intensity. A magnetic field H from a suitable source, not shown, extends longitudinally through the slab 51, as indicated by the arrow. A first contact 53 and lead 54 are connected to one end of member 51, while at the other end are connected contacts 56, 57 and their respective leads 58, 59.

In operation, switching signals propagate along waveguide 52 in a mode having a transverse magnetic field component. This component adds to the magnetic field H within the slab 51 to produce a current path between contact 53 and one or the other of contacts 56 and 57. Reversal of the magnetic field of the wave in the guide produces switching of the current path to the other of contacts 56 and 57.

From the foregoing discussions it can be seen that simple, reliable, high speed switches capable of trouble-free extended life can be realized utilizing the principles of the present invention.

The foregoing embodiments are intended to illustrate the principles of the invention. Numerous other arrangements utilizing these principles may occur to workers in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, a member of magnetoresistive material, said member having a first conductive contact on one surface thereof and one or more other conductive contacts on another surface thereof, means for establishing a magnetic field through the material between the said surfaces, and means for completing an electrical circuit between said first contacts and at least one of said other contacts comprising means for producing a magnetic field in said member at an angle to the first mentioned field, the total magnetic field in said member being sufficient to produce a ratio of transverse magnetoresistance to longitudinal magnetoresistance of 10^2 or more.

2. The combination as claimed in claim 1 wherein the material of said member is bismuth.

3. The combination as claimed in claim 1 wherein the material of said member is antimony.

4. The combination as claimed in claim 1 wherein the material of said member is indium antimonide.

5. A switching device comprising a member of magnetoresistive material having a first conductive contact on one end surface thereof and a plurality of conductive contacts on the other end surface thereof, means for establishing a longitudinal magnetic field within said member and extending between the two end surfaces, a source of switching signals, and means responsive to the switching signals for establishing a transverse magnetic field within said member, the resultant magnetic field in said member extending between said first contact and one of said plurality of contacts and having a magnitude sufficient to produce a ratio of transverse to longitudinal magnetoresistance within the material of 10^2 or more.

6. A switching device as claimed in claim 5 wherein the means responsive to said switching signals comprises a pair of magnetic field producing coils on either side of said member.

7. A switching device as claimed in claim 5 wherein the means responsive to said switching signals comprises a plurality of deflecting coils arranged around said member.

8. A switching device as claimed in claim 5 wherein the means responsive to said switching signals comprises a

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waveguide for propagating said signals and said member is mounted in one wall of said waveguide in a region of transverse magnetic field in said guide.

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3,176,146 3/1965 Dunlap ----- 307—309 X
3,189,762 6/1965 Galpin ----- 330—6 X
3,214,609 10/1965 Drew et al. ----- 307—309

References Cited

UNITED STATES PATENTS

1,822,129 9/1931 Craig ----- 329—192 X
1,938,331 12/1933 Hansell ----- 329—200 X
2,202,376 5/1940 Hansell ----- 329—176 X
3,167,663 1/1965 Melngailis et al. ----- 307—309 X

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