

PATENT SPECIFICATION

DRAWINGS ATTACHED

1002.724

1002.724



Date of Application and filing Complete Specification Oct. 15, 1962.

No. 38926/62.

Application made in United States of America (No. 145803) on Oct. 18 1961.

Complete Specification Published Aug. 25, 1965.

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Index at acceptance:—H3 B(2A, 2D, 3D, 4B2, 4C1, 5A)

Int. Cl.:—H 03 f

COMPLETE SPECIFICATION

Method of and Apparatus for Sensing the Direction of Magnetization of Ferromagnetic Thin Film Devices

We, TEXAS INSTRUMENTS INCORPORATED, of 13500 North Central Expressway, Dallas, Texas, United States of America, a corporation organized and existing under the laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of and apparatus for sensing the direction of magnetization of ferromagnetic thin film devices.

A thin film of ferromagnetic material provides a means for storing binary information due to the fact that uniaxial anisotropy is exhibited by the film. Thin film memory devices are widely used, but ordinarily the information stored in the memory is read out by applying a pulse magnetic field in a direction parallel to the easy axis of the film and sensing whether or not the magnetization vector switches in direction. However, this type of readout is destructive since the pulsed magnetic field must be greater than the value necessary to switch the magnetization vector. After readout, all of the memory bits will be in the same condition, and so the originally stored information is lost unless re-entered.

An object of the present invention is to provide a method of and apparatus for non-destructive readout of ferromagnetic thin film memory devices.

The present invention is a method of sensing the direction of magnetization of a ferromagnetic thin film device, comprising the steps of applying a high frequency electromagnetic field adjacent said device, selectively applying an external magnetic field adjacent said device in a direction generally parallel to the plane of said thin film, and detecting said electromagnetic field adjacent said device while said

external magnetic field is present and also in the absence of said external magnetic field.

The present invention is also apparatus for sensing the direction of magnetization of at least one ferromagnetic thin film device, comprising means for applying an external magnetic field adjacent said thin film device in a direction generally parallel to the plane of said thin film device, and means including a source of high frequency electromagnetic energy coupled to said thin film device for detecting the influence of said external magnetic field upon the permeability of said thin film device. The at least one ferromagnetic thin film device preferably exhibits uniaxial anisotropy in the plane of said thin film device.

The present invention is also an apparatus for sensing the direction of internal stored magnetisation in a magnetisable thin film device possessing uniaxial anisotropy, comprising means for coupling a source of electromagnetic energy having a frequency near the frequency of maximum permeability of said thin film, means for applying a separate external magnetic field to pass through said device in a direction parallel to its anisotropy axis, and means for determining the change in magnitude of the electromagnetic energy passing through said thin film device between a state when the external magnetic field is present and a state when it is absent as an indication of the direction of the internal stored magnetisation of the device.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a pictorial representation of apparatus for providing nondestructive readout of a thin film device in accordance with this invention;

Figure 2 is a graphic representation of

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permeability versus frequency for a thin film utilizing the device of Figure 1;

Figure 3 is a graphic representation of voltage wave-forms appearing in the apparatus of Figure 1;

Figure 4 is a pictorial representation of a multi-bit memory incorporating the readout principles of this invention and providing a selective write-in arrangement;

Figure 5 is an enlarged view of one of the memory bits of Figure 4;

Figures 6a and 6b are graphic representations of voltage waveforms appearing in the apparatus of Figures 4 or 5;

Figure 7 is a graphic representation of magnetic vectors present in a thin film device; and

Figure 8 is a graphic representation of the Larmor precession frequency of a thin film device as a function of applied external field.

With reference to Figure 1, there is shown a readout arrangement for a one bit memory comprising a thin film device in the form of a disc 10. The magnetic thin film memory disc 10 is positioned between a pair of parallel plates 11 which comprise a stripline UHF transmission line 12, part of the top plate being broken away to show the disc 10. A signal source 13 having a frequency of about 500 mc., for example, is connected across one end of the transmission line 12 or between the conductive plates 11. The signal injected at the left-hand end by the source 13 will travel down the line 12 past the memory disc 10 and will be sensed by a suitable detecting device 14 which may comprise a microwave crystal diode detector. A readout winding 15, shown external of the plates 11, surrounds the disc 10 and is excited by a readout pulse generator 16. The pulse generator 16 is adapted to produce an output pulse at the time when it is desired to read out the bit stored in the disc 10. This pulse provides a magnetic field in a direction generally parallel to the plane of the disc and parallel to the axis of the transmission line 12 or the plates 11, this magnetic vector being indicated by an arrow 17. The RF energy travelling along the line 12 will have a magnetic vector in a direction perpendicular to the axis of the line and in a plane parallel to the disc 10 as indicated by an arrow 18.

The memory disc 10 comprises a base member such as a glass plate 20 having a thin film of ferromagnetic material 21 deposited upon one surface thereof. The thin film 21 may be composed of Permalloy, which is a nickel-iron alloy containing approximately 82% nickel and 18% iron, and preferably is about 2000 Å thick. The thin film 21 may be deposited by a conventional evaporation technique, and the degree of uniaxial anisotropy exhibited by the film may be enhanced by a treatment such as annealing. This film 21 will exhibit an easy axis which

should be aligned generally parallel or at a certain acute angle with the axis of the transmission line 12 or with the field provided by the winding 15 which is indicated by the arrow 17.

The capability of the thin film device 10 as a memory depends upon the existence of a uniaxial anisotropy in the plane of the film, meaning that the magnetization vector lies in the plane of the film and parallel to a given axis, usually known as the easy axis. The magnetization vector can exist in only two stable positions, one being arbitrarily designated the zero direction and the other designated the one direction, providing a binary memory. A bit of information is stored in the thin film device 10 by applying an external magnetic field in a direction parallel to the easy axis and of a magnitude sufficient to ensure that the magnetization vector is switched to the desired direction.

The nondestructive readout provided by this invention is based upon the ability to sense the stored bit of information by detecting the change in the UHF permeability of the thin film caused by application of an external field by the winding 15. As will be hereinafter established, the permeability of a ferromagnetic thin film has a maximum value for a particular frequency. In the presence of no external field, the value of this frequency will depend upon the value of the saturation magnetization and anisotropy field of the film. For the above-described embodiment of the film, the frequency of maximum permeability has been found to be about 600 mc. A graph of permeability versus frequency for a particular thin film is illustrated in Figure 2, wherein a line 24 represents the magnitude of permeability exhibited by the thin film device 10 as a function of applied frequency. The line 24 is seen to be centered about a frequency of 600 mc. as explained above. The device 10, however, is excited by a UHF field of a frequency of 500 mc., for example, so that the permeability of the device 10 as it appears in the transmission line 12 will be of a value represented by a point 25 on the line 24 where it intersects the 500 mc. line. Since the frequency of maximum permeability for a thin film is dependent upon the magnetization of the film itself and upon applied magnetic field, this frequency will shift in one direction if the applied field is in the same general direction as the film magnetization vector and will shift in the opposite direction if the applied field is in opposition to the film magnetization vector. Accordingly, the permeability versus frequency characteristic will lie on a line 26, as seen in Figure 2, if a zero is stored or, in other words, if the field produced by pulsing the line 15 is in the same general direction as the magnetization vector of the thin film

device 10. The permeability exhibited by the thin film device 10 to the 500 mc. field may then be represented by a point 27 on the line 26. On the other hand, if a one is stored, or if the field produced by winding 15 is in opposition to the magnetization vector of the film, then the permeability versus frequency characteristic will be defined by a line 28 and the permeability seen by the 500 mc. field will be represented by a point 29. The detector is able to produce a positive pulse if the electromagnetic wave has increased in magnitude and to produce a negative pulse if the electromagnetic wave has decreased in magnitude. The electromagnetic wave passing through the thin film will either gain or lose energy (increase or decrease in magnitude) depending on the imaginary permeability as shown in Figure 2, which in turn is influenced by the combined magnetization of the device due to the internal stored magnetic field and the externally applied magnetic field. Accordingly, when the winding 15 is driven by a pulse 30 as seen in Figure 3a, the output of the detector 14 will exhibit a positive pulse 31 of Figure 3b if a one is stored in the device 10, or will exhibit a negative going pulse 32, as seen in Figure 3c, if a zero is stored. It is immediately recognised that the UHF field slightly greater than the 600 mc. value may be used instead of slightly less than this value, the basic idea merely being analogous to slope detection.

If the magnetic field provided by the winding 15 is kept below a critical level, or approximately one-half the field necessary to switch the magnetization of the thin film device 10, then the pulse 30 applied to the winding 15 will not switch the device from one stable position to the other. In other words, the pulse 30 will not destroy the memorized bit of information if the magnitude is low enough. Also, it should be noted that the orientation of the winding 15 about the transmission line is such that the field provided by the winding has no component in parallel with the magnetic vector of the UHF energy, and therefore there is no output at the detector 14 due to the pulse 30 alone, but only due to the change in permeability in the disc 10 caused by the pulse 30.

The nondestructive readout technique described thus far illustrates only a single bit memory. With reference now to Figure 4, a large number of the thin film devices may be arranged in a matrix, a three word, three bit-per-word, random access, word-organized memory device being shown. The embodiment of Figure 4 also incorporates a selective write-in arrangement. A flat, conductive, nonmagnetic plate 35 is utilized as one conductor of a plurality of parallel transmission lines, while a set of three thin, conductive, nonmagnetic strips 36-38 are provided as the other conductors of the trans-

mission lines. Suitable coaxial-to-stripline input couplings 39-41 are provided for each of the transmission lines or conductors 36-38, each of the couplings 39-41 being connected to a source 42 of UHF energy of the appropriate frequency by means described below. Since it would ordinarily be desired to read out the memory bits in parallel, all of the lines 36-38 would be simultaneously and continuously energized by the UHF input. The opposite end of each of the conductors 36-39 is connected to one of a plurality of output couplings 43-45, which are in turn connected to output devices 46-48 which may include crystal diode detectors and register or indicating means. A set of three sense or readout windings 50-52 are shown separately encircling the plate 35 at spaced parallel positions. The sense windings 50-52 selectively energized with readout signals, such as the pulse 30 of Figure 3a, by readout and write-in pulse generators 53-55. Beneath the intersection of each of the strips 36-38 and each of the windings 50-52 is positioned one of a plurality of thin film memory discs 56, each being similar to the device 10 of Figure 1. The discs 56 are positioned between the conductors 36-38 and the plate 35 so that they are influenced by the UHF energy and by the field provided by the windings 50-52. Readout of a given word may be accomplished by energizing the appropriate one of the word or sense windings 50-52 by one of the source 53-55, the digit lines or strips 36-38 being continuously energized. Readout of a particular bit is of course possible by energizing only one of the digit lines 36-38 with UHF energy while pulsing the appropriate word line.

The system of Figure 4 also includes a write-in scheme using the same strips 36-38 and windings 50-52 as used for readout, except the write-in is by d-c pulses, the UHF playing no part. The digit lines or strips 36-38 are driven by write-in pulse generators 57-59, the outputs of which are connected by directional couplers 60-62 to the input couplings 39-41. The UHF source 42 is connected by coaxial line to the other inputs of the directional couplers 60-62, the purpose of the latter being to isolate the source 42 from the d-c write-in voltages. The write-in technique may be somewhat similar to that described by E. M. Bradley in an article "A Computer Storage Matrix Using Ferro-magnetic Thin films", Journal of the British I.R.E., October, 1960, pp. 765-784. However, in the present scheme each of the thin film devices 56 is oriented such that the easy axis makes an angle of about 11° with one of the digit lines 36-38. This angle is not critical, and may be any value less than 45° , although a small angle provides a better output signal. The write-in mechanism may best be explained by considering a particular

disc 56 disposed beneath the intersection of the line 36 and the winding 50, as seen in Figure 5. The easy axis of the disc 56 lies along a dotted line 64, the right-hand direction being designated as "one" and left hand as "zero". The word line 50 is first energized by the source 53 with a pulse 65 as seen in Figure 6a, producing a field H_w , illustrated

by an arrow in Figure 5. This will unconditionally set all of the discs under the line 50 to "1". Subsequently, a pulse 66 of opposite polarity is applied to the winding 50, producing a field H_w . The magnitude

of H_w is insufficient to switch the magnetiza-

tion to "0", but if a pulse 67 is applied to the digit line 36 at the same time, the critical value may be exceeded and the magnetization switched from "1" to "0". It is noted that the pulse 66 persists after the termination of the pulse 67 so that rotation of the magnetization vector around to the "0" direction will be assured. It is seen that information may be written in one word at a time, all bits in each word line being first set to "1" and then the desired bits being reset to "0".

As explained above, the nondestructive read-out of the thin film device provided by this invention is based upon a shift in the frequency of maximum permeability of a ferromagnetic thin film due to an external magnetic field. A more precise relation between the UHF permeability and the external field will now be derived. As previously stated, Permalloy films with a thickness of less than about 10^4 Å generally exhibit the properties of a single magnetic domain having a uniaxial anisotropy. That is to say, the entire magnetization of the sample prefers to lie parallel to one direction and may be treated as if it were a single vector, M . With reference to Figure 7, if a magnetic field H is applied so that it makes an angle ψ with the magnetization vector, a torque is exerted on M . M will then tend to rotate toward H , but owing to the gyroscopic properties of M , it will not align itself with the field but will precess in a cone about the direction of the magnetic field which is inside of the sample. The frequency of this precession is known as the Larmor precession frequency and is directly proportional to the internal field of the sample.

The internal field in a thin film is different from an external applied field. This difference arises from the presence of demagnetising fields and the anisotropy field. A film having a uniaxial anisotropy may be thought of as possessing an anisotropy field (H_k) along one direction, which tends to keep the magnetisation parallel to it. This direction is known as the easy axis. Thus in the presence of no external field, the internal field will be

H_k . This gives rise to a precession of the magnetisation even in the absence of any applied field. It may be established that the frequency of this precession can be expressed.

$$W_k = J (4\pi M H_k)^{1/2} \quad (1)$$

In Equation 1, W_k is the Larmor precession frequency (approximately 600 mc), M is magnetisation per unit volume, and J is the gyromagnetic ratio (2.8 mc/gauss). If we apply an external magnetic field parallel to the easy axis in the direction of M , the external field will add to the anisotropy field. This yields a new Larmor precession frequency given by the expression.

$$W = J (4\pi M (H_k + H))^{1/2} = W_k (1 + H/H_k)^{1/2} \quad (2)$$

where H is the applied field. If the field is applied parallel to the easy axis but in the opposite direction of M , the external field subtracts from the anisotropy field and the expression for the Larmor precession frequency becomes

$$W = J (4\pi M (H_k - H))^{1/2} = W_k (1 - H/H_k)^{1/2} \quad (3)$$

It must be noted at this point that equation 3 is only valid as long as H is less than the critical field H_k which will cause the magnetisation to change direction. If this critical field is exceeded, the magnetisation will switch from its original position by domain wall movement until it points along the direction of the applied field. Equation 2 will then apply. A graph of W/W_k as a function of H/H_k for the two cases is shown in Figure 8. This analysis has been given only for the case with the field parallel to the easy axis. In actual practice, the same type of behaviour exists when the field is applied at an angle to the easy axis.

It can be further established that the precession frequency of the magnetisation vector affects the UHF permeability exhibited by a thin film. If a UHF magnetic field H_{ext} is placed at about right angles to the precessing vector as seen in Figure 7, this field can apply a torque to the magnetic vector M . The maximum energy can be transferred from the UHF field to the magnetisation vector when the frequency of the UHF field is equal to the precession frequency of the magnetisation vector. This condition is known as resonance.

The permeability of a magnetic sample is a complex quantity and is usually written in the form $\mu = \mu_1 - j\mu_2$. The real part μ_1 is a measure of the frequency dispersion and the imaginary part μ_2 is a measure of the power absorbed by the sample. The imaginary component is the part in which we are interested. In Physical Review, June 1, 1950, p 572, N. Bloembergen expressed this imaginary component as

$$\mu_2 = \frac{(J4\pi M)^2 X}{(W_0^2 - W^2)X^2 + X^2} \quad (4)$$

Where W_0 is the frequency of the UHF wave, W is the Larmor precession frequency, J is the gyromagnetic ratio of the angular momentum to the magnetisation vector, M is the magnetisation per unit volume, and X is a damping term. Thus it is seen that the permeability is a maximum when $W=W_0$ and decreases as W departs therefrom in either direction. It can be established that the real power delivered to the load or the detector 14, assuming that the input 13 is of constant frequency and amplitude, and that the line 12 is essentially lossless except for the device 10, is dependent upon the permeability of the thin film, which is of course related to the external field provided by the winding 15 and upon the direction of magnetisation within the film.

WHAT WE CLAIM IS:—

1. A method of sensing the direction of magnetization of a ferromagnetic thin film device, comprising the steps of applying a high frequency electromagnetic field adjacent said device, selectively applying an external magnetic field adjacent said device in a direction generally parallel to the plane of said thin film, and detecting said electromagnetic field adjacent said device while said external magnetic field is present and also in the absence of said external magnetic field.

2. A method according to claim 1, wherein a magnetization vector is sensed, comprising the steps of exciting said device with an electromagnetic field of a frequency near the frequency of maximum permeability of said device, the magnetic vector of said electromagnetic field being generally parallel to the plane of the thin film, applying a magnetic field adjacent said device in a direction generally parallel to the plane of the thin film, and detecting the influence of the permeability of the thin film device upon said electromagnetic field when said magnetic field is applied.

3. A method according to claim 1, wherein a magnetization vector is sensed, comprising the steps of applying an ultra-high-frequency signal to one end of a transmission line having said thin film device positioned therein, said signal having a frequency near the frequency of maximum permeability of said thin film device, providing a magnetic field within said line surrounding said thin film device in a direction generally parallel to the plane thereof, and detecting said signal at the other end of said line whereby the influence of the permeability of the thin film device upon said signal may be indicated.

4. Apparatus for sensing the direction of magnetisation of at least one ferromagnetic thin film device, comprising means for applying an external magnetic field adjacent said thin film device in a direction generally parallel to the plane of said thin film device, and means including a source of high fre-

quency electromagnetic energy coupled to said thin film device for detecting the influence of said external magnetic field upon the permeability of said thin film device.

5. Apparatus according to claim 1, wherein the at least one ferromagnetic thin film device exhibits uniaxial anisotropy in the plane of said thin film device.

6. Apparatus according to claim 4 or 5, wherein the means including a source of high frequency electromagnetic energy coupled to said thin film device for detecting the influence of said external magnetic field upon the permeability of said thin film device includes means for providing a high frequency electromagnetic field in the area of the thin film of said thin film device and means for detecting the influence of the permeability of said thin film upon said electromagnetic field during the existence of said external magnetic field.

7. Apparatus for sensing the direction of internal stored magnetisation in a magnetisable thin film device possessing uniaxial anisotropy comprising means for coupling a source of electromagnetic energy having a frequency near the frequency of maximum permeability of said thin film, means for applying a separate external magnetic field to pass through said device in a direction parallel to its anisotropy axis, and means for determining the change in magnitude of the electromagnetic energy field passing through said thin film device between a state when the external magnetic field is present and a state when it is absent as an indication of the direction of the internal stored magnetisation of the device.

8. Apparatus according to claim 4, including a transmission line, a source of signals having a frequency near the frequency of maximum permeability of said device connected to one end of said line, said device being positioned within said line in a plane generally parallel to the magnetic vector of said signals, a winding surrounding said device for providing a magnetic field in a direction parallel to the plane of said device and generally perpendicular to said magnetic vector, means for selectively energising said winding with pulses having a magnitude less than required to switch the direction of magnetisation of said device, and detecting means responsive to said signals connected to the other end of said line whereby nondestructive readout is accomplished.

9. Apparatus according to claim 4, wherein the device is a thin memory disc, including a stripline, an ultra-high frequency source connected to one end of said stripline, said source having a frequency near the frequency of maximum permeability of said memory disc, detecting means connected to the other end of said strip line, said detecting means being responsive to said ultra-high frequency



Where W_0 is the frequency of the UHF wave, W is the Larmor precession frequency, J is the gyromagnetic ratio of the angular momentum to the magnetisation vector, M_i is the magnetisation per unit volume, and X is a damping term. Thus it is seen that the permeability is a maximum when $W=W_0$, and decreases as W departs therefrom in either direction. It can be established that the real power delivered to the load or the detector 14, assuming that the input 13 is of constant frequency and amplitude, and that the line 12 is essentially lossless except for the device 10, is dependent upon the permeability of the thin film, which is of course related to the external field provided by the winding 15 and upon the direction of magnetisation within the film.

WHAT WE CLAIM IS:—

1. A method of sensing the direction of magnetization of a ferromagnetic thin film device, comprising the steps of applying a high frequency electromagnetic field adjacent said device, selectively applying an external magnetic field adjacent said device in a direction generally parallel to the plane of said thin film, and detecting said electromagnetic field adjacent said device while said external magnetic field is present and also in the absence of said external magnetic field.

2. A method according to claim 1, wherein a magnetization vector is sensed, comprising the steps of exciting said device with an electromagnetic field of a frequency near the frequency of maximum permeability of said device, the magnetic vector of said electromagnetic field being generally parallel to the plane of the thin film, applying a magnetic field adjacent said device in a direction generally parallel to the plane of the thin film, and detecting the influence of the permeability of the thin film device upon said electromagnetic field when said magnetic field is applied.

3. A method according to claim 1, wherein a magnetization vector is sensed, comprising the steps of applying an ultra-high-frequency signal to one end of a transmission line having said thin film device positioned therein, said signal having a frequency near the frequency of maximum permeability of said thin film device, providing a magnetic field within said line surrounding said thin film device in a direction generally parallel to the plane thereof, and detecting said signal at the other end of said line whereby the influence of the permeability of the thin film device upon said signal may be indicated.

4. Apparatus for sensing the direction of magnetisation of at least one ferromagnetic thin film device, comprising means for applying an external magnetic field adjacent said thin film device in a direction generally parallel to the plane of said thin film device, and means including a source of high fre-

quency electromagnetic energy coupled to said thin film device for detecting the influence of said external magnetic field upon the permeability of said thin film device.

5. Apparatus according to claim 1, wherein the at least one ferromagnetic thin film device exhibits uniaxial anisotropy in the plane of said thin film device.

6. Apparatus according to claim 4 or 5, wherein the means including a source of high frequency electromagnetic energy coupled to said thin film device for detecting the influence of said external magnetic field upon the permeability of said thin film device includes means for providing a high frequency electromagnetic field in the area of the thin film of said thin film device and means for detecting the influence of the permeability of said thin film upon said electromagnetic field during the existence of said external magnetic field.

7. Apparatus for sensing the direction of internal stored magnetisation in a magnetisable thin film device possessing uniaxial anisotropy comprising means for coupling a source of electromagnetic energy having a frequency near the frequency of maximum permeability of said thin film, means for applying a separate external magnetic field to pass through said device in a direction parallel to its anisotropy axis, and means for determining the change in magnitude of the electromagnetic energy field passing through said thin film device between a state when the external magnetic field is present and a state when it is absent as an indication of the direction of the internal stored magnetisation of the device.

8. Apparatus according to claim 4, including a transmission line, a source of signals having a frequency near the frequency of maximum permeability of said device connected to one end of said line, said device being positioned within said line in a plane generally parallel to the magnetic vector of said signals, a winding surrounding said device for providing a magnetic field in a direction parallel to the plane of said device and generally perpendicular to said magnetic vector, means for selectively energising said winding with pulses having a magnitude less than required to switch the direction of magnetisation of said device, and detecting means responsive to said signals connected to the other end of said line whereby nondestructive readout is accomplished.

9. Apparatus according to claim 4, wherein the device is a thin memory disc, including a stripline, an ultra-high frequency source connected to one end of said stripline, said source having a frequency near the frequency of maximum permeability of said memory disc, detecting means connected to the other end of said strip line, said detecting means being responsive to said ultra-high frequency



and adapted to produce an output signal related to the magnitude thereof, said memory disc being positioned within said stripline intermediate said ends, a winding encircling said stripline adjacent said memory disc, and means for momentarily energising said winding.

10. Apparatus according to claim 4, including a flat conductive member, a plurality of flat conductive strips positioned in a generally parallel spaced relationship adjacent one surface of said member, a plurality of separate windings surrounding said member and said strips in a generally parallel spaced relationship to one another, the at least one device being a plurality of ferromagnetic thin film memory elements, one of said elements being positioned adjacent the intersection of each of said windings and each of said strips, said memory elements being interposed between said strips and said member, means for applying high frequency energy to one end of each of said conductive strips, means for selectively energizing each of said windings, and means for detecting the high frequency energy at the other end of each of said conductive strips, whereby nondestructive readout is accomplished.

11. Apparatus according to claim 4, including a flat conductive member, a plurality of flat conductive strips positioned in a generally parallel spaced relationship adjacent one surface of said member, a plurality of separate windings surrounding said member and said strips in a generally parallel spaced relationship, the at least one device being a plurality of ferromagnetic thin film memory elements, one of said elements being positioned adjacent the intersection of each of said windings and each of said strips, said elements being interposed between said strips and said member, the easy axis of each of said elements

being oriented at an acute angle with said strips and said windings, means for coupling ultra-high frequency energy to one end of each of said strips, said energy having a frequency near the frequency of maximum permeability of said elements, pulse generating means for selectively applying pulses to said strips and said windings for establishing and sensing the direction of magnetization in said elements, and means for detecting said energy at the other end of each of said strips whereby nondestructive readout is accomplished.

12. Apparatus according to claim 11, wherein said pulse generating means is adapted to apply first a large pulse to one of said windings in order to set the direction of magnetization in each of the elements thereunder, said pulse generating means being adapted to switch thereafter the direction of magnetization in selected elements under said winding by applying pulses in coincidence to said winding and to said strips which intersect said winding over said selected elements, each of said later pulses being individually smaller in magnitude than necessary to switch the direction of magnetization of said elements.

13. A method of sensing the direction of magnetization of a ferromagnetic thin film device substantially as hereinbefore described with reference to Figs. 1 to 3 or Figs. 4 to 6b of the accompanying drawings.

14. Apparatus for sensing the direction of magnetization of a thin film device substantially as hereinbefore described with reference to Figs. 1 to 3 or Figs. 4 to 6b of the accompanying drawings.

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