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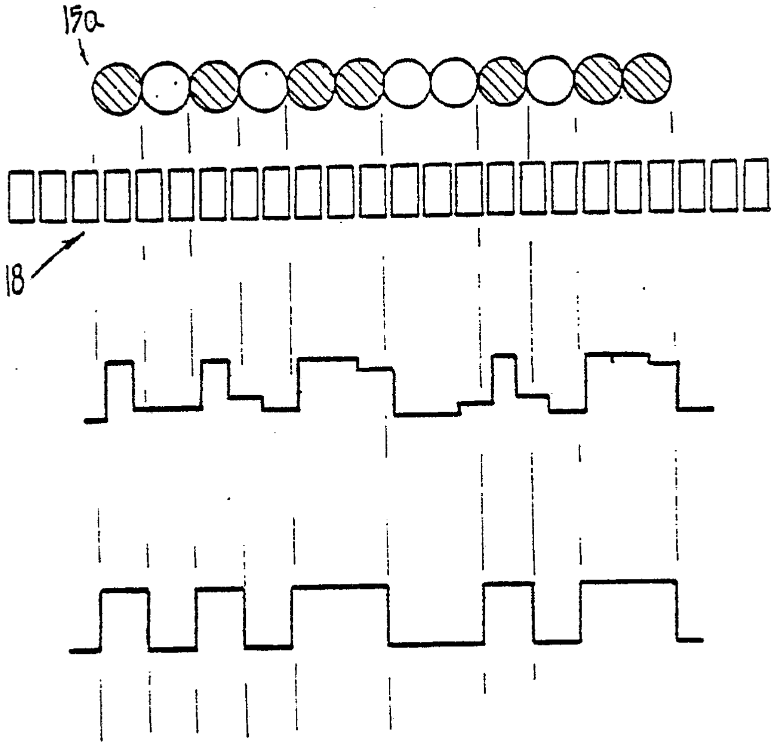
(54) Title: READING INFORMATION STORED IN MULTIPLE FRAME FORMAT

(57) Abstract

A method of reading information stored in a medium in one or more channels (14) of successive record frames (15) each containing a plurality of discrete record entries (15a) indicative of values from a limited set of possible values. Each frame is observed in turn with a substantially known array (16) of detector elements (18) such that each record entry influences the state and/or output of at least one detector element, whereby to produce a first set of observed values (Fig 4B) for each frame represented by the states and/or outputs of the detector elements. The limitations on the range of the aforesaid possible values are then utilised to derive from the observed values for each frame a set of modified values indicating record entries of the frame. One or more marker patterns are identified among the modified values, and such marker pattern(s) then utilised to derive from the modified values an accurate representation (Fig 4C) of the record entries of the frame. The derivations are effective to correct for any misregistration between the record entries and the detector elements.



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"READING INFORMATION STORED IN MULTIPLE FRAME FORMAT"

This invention relates to the reading of information stored in a medium in one or more channels of successive record frames each containing a plurality of discrete record entries. More particularly, the invention is concerned with overcoming misregistration between the record entries and the detector elements of the reading head, with a view to rendering more practical the storage of digital data in optically scannable form such as on photographic film or on microfiche.

Various arrangements have been proposed for reading digital data encoded on optically sensitive media. These have included semi-mechanical devices involving steerable mirrors in an optical magnifier disposed between the record frames and optically responsive detection equipment. Such devices are shown, for example, in United States patent 4,251,126 to Minoura et al, 3,072,889 to Willcox and, in the context of videodiscs in United States patent 4,118,735 to Wilkinson. For higher speed readout, an optically based system employing prism optics to project images of multiply coloured record frames onto successive charge storage detectors, is disclosed in United States patent 3,959,784.

While attention is devoted in the art to achieving improved readout speed, frame registration and correction for defocusing effects, the present inventor believes that the question of compensating for misregistration within a frame has not been adequately addressed. The traditional approach has been to simply ensure sufficient mechanical precision in the location of read heads with respect to the channels in which the record frames are arranged. In the case of magnetic tape storage, for example, the 7 or 9 heads each read their own track, and the tape is aligned mechanically to prevent a read head reading the wrong track.

As the density of data increases, the mechanical difficulty of this operation also increases and the cost of the required mechanism rises. This effect is demonstrated in the case of video discs, where a single laser beam is servo guided along a track 1 micron wide. United States patent 3,919,697 to Walker discloses an arrangement in which the data channels or tracks are bordered and separated by "tracking information" to maintain head alignments.

It will be appreciated that, in the present context, misregistration may refer to the case where the detector elements are displaced by an integral multiple n of record entry spacings, in the case of digital data bit spacings, or to the case of fractional misregistration. It is believed that were the problem to be adequately overcome, the storage of data, especially digital data on photographic film, must notably on microfiche, would become a highly attractive proposition. The advantages of microfiche storage over, for example, magnetic tape storage are appreciated but the substitution would not be economically feasible for the reasons explained. Magnetic tapes recorded at 10,000 bits per linear inch, can store 160,000 bits per square inch, while optical media, at 30 square microns per bit, can provide a data density 134 times greater. In situations such as distribution of information, where a read-only facility is appropriate, this increase in data density can provide significant advantage, providing the reader does not have to achieve a commensurate physical registration, which would involve high costs.

In accordance with the present invention, it is proposed to overcome misregistration, both integral and fractional, by manipulation of the initial detector values, in most cases without attempting to achieve actual registration.

The invention accordingly provides in one aspect, a method of reading information stored in a medium in one or more channels of successive record frames each containing a plurality of discrete record entries indicative of values from a limited set of possible values, characterized by observing each frame in turn with a substantially known array of detector elements such that each record entry influences the state and/or output of at least one detector element, whereby to produce a first set of observed values for each frame represented by the states and/or outputs of the detector elements, utilising the limitations on the range of said possible values to derive from the observed values for each frame a set of modified values including record entries of the frame, identifying one or more marker patterns among the modified values, and utilising the marker pattern(s) to derive from said modified values, an accurate representation of the record entries of the frame, said deriving steps being effective to correct for any misregistration between the record entries and the detector elements.

The array of detector elements is preferably of greater span than each record frame, such that the detector can observe record entries from more than one frame. The record entries and the detector elements will typically be equispaced in linear arrays. The array may be defined by one or more detectors arranged to observe successive spatial positions at which they form transitory detector elements.

Alternatively, the detector elements may comprise segments of a continuous linear detector arranged so that the values observed by each segment can be output separately from the values observed by other segments.

In a preferred embodiment outputs from successively positioned detector elements are successively presented at regular intervals, said modified values, while being restricted to values representing only said possible values, are produced at times which vary from the times of presentation of the detector element outputs in a way which reflects the magnitudes of the detector outputs.

According to a further embodiment, the readable values are the binary numbers 1 and 0, the centre-to-centre spacing between detector elements and between record entries, as presented to the detector elements, is equal and uniform, and the set of modified values is derived in part by serially carrying finite observed values less than a prescribed first threshold, itself substantially less than the observed value representing the possible value 1, for addition to respective, serially ordered, other observed values such that the resultant summations exceed said first threshold, but subject to each carried value not exceeding the observed value to which it is added by an amount greater than a second threshold.

According to a still further embodiment, the states and/or output of the detector elements are read serially so as effectively to produce a time based analogue signal comprising said set of observed values, and said modified values are derived therefrom by analysis of said analogue signal. This analysis can be effected for example, by the use of digital communication circuitry such as a universal asynchronous receiver/transmitter (UART).

The record entries are advantageously optically scannable zones of variable or varying opacity and the medium is then suitably photographic film, for example in microfiche format.

Said marker pattern(s) are typically unable to be replicated in the data, advantageously identify the start and/or end of the respective frames, and are preferably utilized to assign positions and hence significance to each record entry independently of the detector element(s) used to observe it.

The invention is also directed to apparatus for carrying out the aforesaid method characterized by a holder to temporarily support or retain said medium; a substantially known array of detector elements moveable relative to said holder; means to scan each frame in turn with said array such that each record entry influences the state and/or output of at least one detector element, to produce a first set of observed values for each frame represented by the state and/or outputs of the detector elements; and means for utilising the limitations on the range of said possible values to derive from the observed values for each frame a set of modified values including record entries of the frame, identifying one or more market patterns among the modified values, and utilising the marker pattern to derive from said modified values, an accurate representation of the record entries of the frame, said deriving means being effective to correct for any misregistration between the record entries and the detector elements.

Said scanning means may include a drive arranged to selectively relatively move the array of the medium in either or both of two mutually perpendicular directions, preferably such that these directions are parallel to the record frames and parallel to the channels of the medium. In practice, it is believed that it may be preferable to physically move the holder rather than the array of detector elements.

Alternatively, for optically scanning record entries, the scanning means may include a cylindrically curved mirror disposed so that the record frame of a medium in said holder lies on the face of the mirror, and a further mirror mounted substantially at the axis of curvature of the cylindrical mirror for rotation about an axis parallel to said axis of curvature, whereby optical paths are successively provided between the record frames of a channel and the array of detector elements.

In an alternative embodiment for optically scanning record entries, the scanning means includes a spherical or paraboloidal concave mirror or convex lens disposed to face the record frame of a medium holder,and a further smaller mirror mounted substantially at the focus of the concave mirror for rotation about at least one axis, whereby optical paths are successively provided between the record frames of a channel and the array of detector elements.

In a separate aspect, the invention provides a semiconductor device comprising a Field-effect transistor layer which has one major face in electrically conductive contact with a photoelectric or magneto-electric layer and another major face in electrically conductive contact with a juxtaposed conductor layer, and a strip of material in proximity to the gate of the Field-effect transistor layer selected whereby on propogation of a wave in said material a voltage is generated which opens a moving conduction window in the Field-effect transistor layer.

The invention will be further described, by way of example only, with reference to the accompanying diagrams, in which:-

Figure 1 shows an arrangement for successively observing record frames in a microfiche medium;

Figures 2 and 3 show alternative arrangements for observing record frames in any medium in which the record entries are optically scannable;

Figure 4A represents a frame of record entries, in the form of binary bits, and an array of detector elements, the frame and the elements being misregistered both integrally and fractionally;

Figure 4B represents the set of values observed by the array of detector elements of Figure 4;

Figure 4C represents a set of modified values derived from the observed values of Figure 4B in accordance with an embodiment of one aspect of the invention, the modified values indicating record entries of the frame shown in Figure 4A; and

Figure 5 is a cross-section of a semi-conductor device in accordance with another aspect of the invention.

For the purposes of explanation, the ensuing discussion shall be based upon a number of simplications. It will be assumed that the medium in which the information is stored is a microfiche, and that such information comprises digital data arranged in a series of linear record frames in one or more parallel channels. The frames extend perpendicularly to the channels and the record entries are indicative of the binary numbers 1 and 0, these comprising the limited set of possible values. Hence, the record entries, which might for example comprise spots of substantially variable opacities, will herein be referred to as bits, but it is to be emphasized that none of these simplifications constitute limitations on the ambit of the invention. For example, the record entries might be spots of magnetization or transitions from one value of opacity, or one magnetic field intensity or direction, to another.

Figure 1 shows a simple cartesian arrangement by which the bits in the microfiche might be observed. The microfiche 10 is placed in a holder 12 so that the channels 14 of data are aligned in a specific direction. Extending perpendicularly to this direction is a read head 16 having multiple detector elements. Associated with holder 12 is a drive 13 not detailed, by which the holder may be moved either parallel to the channels or parallel to the frames 15 or both so as to selectively relatively move the array of detector elements relative to the medium in either or both of these two mutually perpendicular directions. Drive 13 might comprise a threaded rod rotated by a motor, or an inelastic string or wire wound around a drum connected to a motor. It would be preferred that the drive moved the microfiche at substantially constant velocity parallel to the data channels and perpendicularly to the frames, but in a stepwise motion parallel to the frames and perpendicular to the channels. For this purpose, drive 13 may comprise an electric stepping motor to move the holder and the microfiche parallel to the frames and a separate electric motor operating at constant velocity to move the microfiche for observation of successive frames in the selected channel.

Two alternative scanning techniques applicable only to optically observable record frames such as in microfiche or microfilm, both utilizing rotating mirrors are depicted diagrammatically in Figures 2 and 3. In the Figure 2 arrangement, a cylindrically curved mirror 20 is disposed so that a selected record frame of a medium in a holder 22 lies on the face of the mirror 20. Mirror 20 is either stationary (as it might be with microfilm) or is moveable in a direction parallel to its axis of curvature (as it might be with microfiche). A further mirror 24 is mounted substantially at the axis of the curvature of cylindrical mirror 20 for rotation about an axis parallel to the axis of curvature of mirror 20. In this manner, optical paths are successively provided between the record frames of a channel and an array of detector elements 28. Mirror 24 might sweep over the angle subtended by the medium at the axis of the rotatable mirror. Mirror 24 would typically sweep up and down in a simple harmonic or linear fashion so that all frames in each channel could be observed.

In the Figure 3 arrangement, a spherical or paraboloidal concave mirror 30 is disposed to face the record frames of the medium in a holder 32. A further smaller mirror 34 is mounted substantially at the focus of concave mirror 30 for rotation about at least one axis. Mirror 34 may rotate about both of two perpendicular axes: rotation about one axis would select channels, while rotation about the other axis would cause light from successive frames of the selected channel to fall on a stationary optical detector array 38.

A particular application of the latter scanning arrangement would employ a stationary spherical mirror of a circumference slightly larger than $\Pi\sqrt{W^2 + (\ell/2)^2}$ where W and ℓ are respectively the width and length of the microfiche constituting the storage medium. The radius of curvature of this mirror would be selected in accordance with dimensions of the reading equipment and with resolution or depth of field criteria. The circumference of the mirror would lie in a plane parallel to the plane of the microfiche, which would be held against another flat mirror. The microfiche is then positioned so that the axis of the stationary spherical mirror does not pass through the microfiche, but all light rays passing therethrough in a direction perpendicular to its surface would strike the stationary spherical mirror. The rotating mirror, at the centre of focus of the stationary mirror, can then direct a light beam if intersected onto any part of the microfiche, while light rays from any particular part of the microfiche can be redirected by the moving mirror to a stationary detector. Since a large portion (almost half) of a stationary spherical mirror would not be used, such part could be omitted.

The respective arrays of detector elements

18, 28, 38 of each of the above techniques develops a set of observed values for each frame represented by the states and/or outputs of the detector elements. The elements are coupled to compensation circuitry 19, 29, 39 effective to correct for any misregistration between the bits and the detector elements. As discussed, one form of such misregistration is fractional misregistration, in which at least some of the detector elements are positioned to observe more than one of the bits. It is this aspect of the invention which will now be discussed in detail. Essentially, it is proposed to utilize the known limitations on the range of possible values to derive from the observed values for each frame a set of modified values indicating record entries of the frame. In the particular case at hand, the "possible values" are limited to the binary numbers 1 and 0.

Reference is first made to the case of serial observation of the bits of each record frame. At any one point in time, only the output corresponding to one bit or a fraction of a bit is available. The data in a whole frame is obtained from a sequence in time of observed values which refer to points along the frame as displacement relative to one end steadily increases.

According to a first embodiment of this aspect of the invention, outputs from successively positioned detector elements are successively presented at regular intervals. The aforementioned modified values, while being restricted to values representing only the possible values 1 and 0, are produced at times which vary from the times of presentation of the detector element outputs in a way which reflects the magnitudes of the detector outputs. The method relies on the fact that a detector element observing part of a bit, typically a spot(s) or transition, will have an output lower than one observing spot centrally or observing a continuous section where a particular degree of opacity prevails. If that lower output is converted to a delay, from the time when that detector element output is presented to the time when the output changes from a 1 to a 0 or vice versa, then a smaller number of detector elements per bit can be used. Transitions from 1 to 0 are delayed in proportion to the difference between the leading detector element output and that corresponding to a 0, and transitions from 0 to 1 are delayed in proportion to the difference between the leading detector element output and that corresponding to a 1. According to one approach, compensation circuit 19,29, or 39 monitoring the outputs of the detector elements would be arranged to obey the following rules:

(a) If the output was low, corresponding to a "0" bit and the next detector element observed shows an output somewhere between the lowest and highest outputs, then produce a transition from a "0" to a "1", at a time after the output presentation proportional to the difference between the highest output and the output observed.

The constant of proportionality should be such that an output or observed value actually at the lowest level (corresponding to a "0") would produce a delay at least until the next observed value was presented, at which time the circuit would be reset.

(b) If the output was high, corresponding to a "1" bit, and the next detector shows an output between the highest and lowest outputs, then delay the transition to a zero for a time proportional to the difference between the observed output and the lowest output. The constant of proportionality would be the same.

The resultant derivation is illustrated in Figures 4A to 4C. Figure 4A shows a frame of record entries, in this case bits represented by two well distinguished degrees of opacity. A linear array of detector elements 18 is brought to an observation position - it will be noted that the spacing of the detector elements is less than that of the bits but that there is no integral ratio involved. The set of observed values is shown in Figure 4B, while Figure 4C depicts the result of applying the derivation rules outlined above: it will be seen that these "modified values" accurately represent bits in the frame.

In a variation of this method, the signal comprising the set of observed values (Figure 4B) is converted to an electrical current the magnitude of which is zero at the lowest observed value, and is proportional to the difference between that value and the currently observed value. This current signal is then employed to charge a capacitor having a capacity chosen so that all outputs corresponding to maximum observed values (e.g. low opacity) are sufficient to charge the capacitor to a predetermined threshold level. Whenever the voltage of capacitor reaches that level, a modified value of 1 is written for 1 detector time, and the capacitor is discharged.

According to a second embodiment of that aspectof the invention concerned with correcting for fractional misregistration, the states and/or outputs of the detector elements are read serially so as to produce a time based analogue signal comprising a set of observed values, and modified values representing the bits of the frame are derived therefrom by a more direct analysis of the analogue signal which relies on each spot or transition being observed by several detector elements or segments.

A novel semiconductor device for reading the detector elements in this manner is depicted in cross-section in Figure 5. A Field-effect transistor layer 40 is sandwiched between, and in electrically conductive contact at respective major faces with, a continuous linear detector 42 and a conductor layer 44. A strip of piezo-electric or like material is disposed in proximity to the lengthwise extending gate of layer 40, so that, on propagation of a wave in material 46, a voltage is generated which opens a moving conductive window in the Field-effect transistor layer 40. Thus, detector 42 can be viewed as an infinite array of detector elements which comprise segments of the detector arranged so that the values observed by each segment can be output separately from the values observed by other segments.

To extract digital data from the signal output at conductor layer 44, the signal might be transmitted directly to high frequency digital communication circuitry as if it were coming over a telephone or co-axial link. Normally, it would not be necessary to de-modulate the signal because of the wide band width (including zero hertz) of the detector. The signal would normally be treated as if it were coming from a modem (modulator/ demodulator). In a particular application, derivation of the modified values representing the bits in the frame is effected by employing a universal asynchronous transmitter/ receiver (UART). The UART would extract a number of bits of data, typically 7 or 8, from a larger number of bits, typically 10.

In a variation of this second embodiment, the voltage signal from the semiconductor device would be differentiated and rectified before being passed to the UART.

Thus, any change, e.g. from low capacity to high capacity or vice versa, would result in a one bit, while the absence of such a change would correspond to a zero bit.

In a further variation of the second embodiment correcting for fractional misregistration, the analogue detector is simulated by an array of discrete detector elements in which there is a sufficiently large number of elements per frame bit. It is believed that at least 3 to 4 detector elements per bit would be required.

A third embodiment for correcting for fractional misregistration is applicable to static or parallel observations, in which the outputs of all the detector elements of the array are simultaneously available. For this method, the possible values for each record entry are specifically the binary numbers 1 and 0, and the centre-to-centre spacing between detector elements and record entries, as presented to the detector elements, is equal and uniform. The set of modified values representing the record entries is derived in part by serially carrying finite observed values less than a prescribed first threshold, itself substantially less than the observed value representing the possible value 1, for addition to respective, serially ordered, other observed values such that the resultant summations exceed the aforementioned first threshold, but subject to each carried value not exceeding the observed value to which it is added by an amount greater than a second threshold.

An important point is that each detector element output may not necessarily be added to the adjacent output, but may be carried to an output several positions away. This carry and add operation is done when the adjacent detector element has an output substantially corresponding to correct registration with the bit, or two bits whose values correspond to high outputs both observed by the next, or subsequent skipped, detector element.

This further embodiment derivation may be considered to obey the following rules:-

(a) Where a detector element has an output below the aforesaid threshold, generally significantly below the usual maximum output, then that output should be carried forward for addition to the output of a subsequent detector element.

(b) The detector array is then scanned in one direction for another detector element whose output is below another but similarly valued threshold. The carried output is then added to that of the second detector element.

(c) This process must be applied to both directions to yield the greatest possible lattitude with threshold settings and detector sensitivities

(d) Where the carried value exceeds the output value to which it is added by a determined threshold, the carry direction is incorrect, and the other carry direction should be chosen.

(e) Where a sum of two detectors exceeding a minimum threshold is made, and does not exceed the aforesaid threshold established to identify a one bit, or a 0 bit if high output values correspond to zeroes, then this indicates that the carry direction used to generate the sum is incorrect, and the other carry direction should be chosen.

A particular implementation of the derivation method according to this third embodiment can be used to illustrate the operation of the method. Suppose an optical medium such as microfilm or microfiche is used to store bits in the general format already described, and that each bit is represented by a spot. Suppose further that a transparent spot providing light to a detector represents a 1 bit, while opacity represents a 0 bit.

If the medium is misregistered with reference to the detector elements by half the spacing between spot centers, and this spacing, as presented to the detector elements, equals the detector spacing, each detector will observe two halves of two adjacent spots. Then a bit sequence along a frame of 001001110 will result in detector outputs (observed values) of 0,0,.5,.5,0,0.5,1,1,0.5, if the maximum detector output is adjusted to be one. The analogue carry of the first 0.5 value will be to the adjacent 0.5 value and will result in a one bit being observed in the 4th detector element assuming carry is to the right (increasing number of detector elements). However, the carry of the 6th detector element will be to the 9th element, resulting in a one bit in that position. Thus detector elements 4,7,8, and 9 will record one bits. A carry in the opposite direction would result in detectors 3, 6,7, and 8 recording one bits.

If instead, the misregistration is less than half the spacing between spot centers, then values such as 0.8 and 0.2 would be observed. The possibility, due to variations in gain, arises that a 0.8 value may exceed the carry threshold, and be identified as a 1 value in its own right, rather than being carried forward to be added to a subsequent 0.2. This would result in a bit being misplaced. Rule (d), supra, eliminates this possibility.

A fourth embodiment of the invention directed to correction for fractional misregistration is also applicable to static or parallel observation of each frame, but is more especially applicable where there are two or more detector elements in sub-arrays of uniform configuration per record entry. In general, the set of modified values representing the record entries is derived by ignoring observed values for detector elements at one or more corresponding positions in all the sub-arrays when a predetermined proportion of such elements give observed values sufficiently different from those corresponding to the possible values. Such possible values are typically the binary numbers 1 and 0.

In this method, the detector is considered as a sequence of n-tuples of detector elements such as pairs or triples of detector elements. If a sufficient number of detector elements in a corresponding position in each n-tuple produce output (observed) values sufficiently below the maximum, then the outputs of those detector elements are ignored, and the bit values are determined from other detector elements in the n-tuples.

A particular arrangement according to this fourth embodiment has detectors spaced at half the bit spacing, (after any optical magnification) of spots forming record entries on an optical medium. Thus a spot could illuminate exactly two detectors, or could fully illuminate one detector and half illuminate the two adjacent detector elements. In the latter case, whenever the bits being observed were not all of the same value (0 or 1), at least one detector element would be half illuminated. By discarding the output from that detector element and all detector elements spaced an even number of elements from it, only detector elements which received full illumination for a 1 bit (assuming bits valued 1 are represented by low opacity), would be used to determine bit values.

Where a spot illuminates a smaller fraction of a detector (say 0.2 of it), threshold values could be used to determine whether this is a ground for rejection of that detector output and others in that position within the other n-tuples.

A fifth embodiment for correcting for fractional misregistration may be employed where the possible values for the record entries are limited to the binary numbers 1 and 0, and where the detector elements are an integral multiple n, including n = 1, of the record entries. In accordance with this embodiment, the set of modified values representing each frame is derived by effecting small changes of the apparent positions of the record entries relative to the array of detector elements until a set of substantially only 1 and 0 values is obtained.

Thus detector outputs are only accepted when no partial outputs are observed. The required relative movements can be achieved by physical vibration of the detector, or the medium, or by recording each bit as a bar at a specified angle to the direction of the normal direction of the medium relative to the detector. Such bars would extend along the channel but vary in position with reference to the side boundaries of the channel.

By way of example, bits may be recorded on an optical medium, not as spots,but as lines aligned at an angle, say 30^{o},to the direction of motion of the detector head with respect to the medium i.e. along the channel. The lines would have a thickness approaching their spacing between centre when measured along the frame (perpendicular to the channel), for optimum packing density. Suppose 0 bits are represented by opacity, and one bits are represented by lines of light, and that the detector element spacing along the frame matches the line spacing along the frame. Then a light might begin by illuminating two detector elements but as the detector head moved along the channel, the line would at some point, provided it was long enough, illuminate only one detector element. When this condition was detected by an absence of output values part way between the output value for a 0 bit and the output value for a 1 bit, the detector outputs would be sampled, and the bit values determined.

Even when one of the aforedescribed embodiments,all reliant on the limitations on the range of possible values is utilized to derive a set of modified values indicating record entries for each frame, the modified values may be associated with detector elements in a manner which involves integral misregistration. By this is meant misregistration, or "misalighment" by a whole number of detector elements or record entries spacings. The second aspect of the invention is directed to correcting for this form of misregistration and entails identifying one or more marker patterns among the modified values, and utilizing the marker patterns to derive, from the modified values, an accurate representation of the record entries of the respective frame.

According to a first embodiment of this second aspect of the invention, once a sequence of bits which match the bits on the medium is obtained, it is placed in a shift register, and shifted until the known pattern, unable to be replicated in the data, is observed in a particular sequence of bits.

In an exemplary method the data is coded so that each subsection of it must have at least one bit set to a 1. Then a pattern consisting of a sequence of 0 bits, longer than any such subsection, may be used as a marker to identify a particular part of the respective frame. This part may be the start, or end, or some position within the sequence. In this way, the marker pattern is utilised to assign positions and hence significance to the record entries independently of the detector element(s) used to observe them. Naturally, a binary complement of this arrangement, in which data subsections contain at least one 0 and the pattern consists of all 1 bits, could be used. Also, two or more occurrences of the same pattern, or two or more different patterns, could be used as a single or multiple markers.

According to a second embodiment, where detector elements in a linear array are successively or serially observed, the known marker pattern may be detected by counting successive bits until a bit is observed which does not match the pattern or until the count of matching bits reaches the length of the pattern.

By way of example, consider the case where all bits in the known pattern have the same value. As successive bits are detected, a counter or electronic shift register increments if the bit detected was of that value, and resets if not. When the counter reached a certain value equal to the length of the known pattern, the pattern would be deemed to be observed.

When, instead, bits of both values (0 and 1) were used in the pattern, the counter would be incremented when a bit corresponding to the first bit value was observed. Thereafter, bits would be compared with bit values selected by the count. A match would result in a further increment to the counter, and a difference would result in the counter being reset. The selection could be arranged by reference to a memory indexed by the counter value, or by the value of a binary identification circuit directly connected to the device(s) storing the counter value. A more specific arrangement would use the value of a particular bit in the counter as the required bit, or the complement of the required bit.

To exemplify these principles, reference is made to Figures 4A to 4C. The set of modified values represented in Figure 4C commences with the pattern 1010 which is not replicated in the rest of the set. If the apparatus has been informed that 1010 is a marker pattern indicating the start of data, or more specifically that the data comences with the next bit, it will be able to locate the residual modified values as an accurate representation of the frame and thereby correct for the random misregistration by whole detector element spacings. This might be done by counting the modified values as outlined above. When a count of 4 is reached, the marker pattern will have been identified.

In some cases, it may be necessary to make provision to correct for physical expansion or contraction of the medium in which the information is stored, or of the spacing between the detector elements, or of the detector where elements are defined by a continuous detector, or of changes in magnification of light from optical media.

With optical media, this could be overcome by automatic changes to the magnification, arranged by electrically driven assemblies which move the optical system relative to the medium and detector, or the detector or the medium relative to the other components.

A particular arrangement of this method could be to mount a lens system on a threaded rod or rods which were rotated by electric motors under control of the computer system receiving the data read from the medium, achieving a small linear movement parallel to the axis of the threaded rods, which axis would be parallel to the primary ray passing through the optical system.

Alternatively methods apply to the Dynamic/Serial methods of overcoming fractional bit spacing misregistrations. A first method would be to adjust the clock frequency governing sampling of data as it was produced, as observed values, by the detector system. An increase in the size of the storage medium (after magnification) relative to the detector element spacing, could be compensated by increasing the time between successive sampling of the observed values.

By way of example, this method might use a voltage controlled oscillator or pulse generator and entail changing the controlling voltage by loading a digital to analogue converter from the computer receiving the data, or by allowing this computer to increment or decrement the voltage with positive and negative charge-pumps connected to the capacitor in a sample-and-hold circuit.

Another method applicable to Dynamic/Serial reading techniques is to reduce the number of bits over which time must be correct to less than the number of bits in a frame. This would allow long frames offering high packing density, and would still allow some accommodation of size change.

An example of this method is to introduce (self) clocking information into the data recorded on the medium. Alternatively, one might use phase-encoding methods, where each bit position is indicated by a transition in one direction, and the value at the bit is determined by the delay from that transition to a transition in the reverse direction. A still further approach might be to record data on the frame in n-tuples begining with a bit of known value. When this bit is detected, a clock is started and n - 1 or fewer bit values are sampled at subsequent clock pulses. Thus the clock need only be accurate over n bits. If, for example, a variation of 40% of a bit time could be allowed in the sample time relative to the start of a bit and n was chosen to be 10, a 4% change in size or magnification could be accommodated without adjustment of clocks or optical systems. An additional advantage of this method is that the known pattern used to identify the start (or other position) of a frame could be a pattern of bits whose values were all opposite to the value of the first bit of each data n-tuple.

CLAIMS

1. A method of reading information stored in a medium in one or more channels of successive record frames each containing a plurality of discrete record entries indicative of values from a limited set of possible values, characterized by observing each frame in turn with a substantially known array of detector elements such that each record entry influences the state and/or output of at least one detector element, whereby to produce a first set of observed values for each frame represented by the states and/or outputs of the detector elements, utilising the limitations on the range of said possible values to derive from the observed values for each frame a set of modified values indicating record entries of the frame, identifying one or more marker patterns among the modified values, and utilising the marker pattern(s) to derive from said modified values, an accurate representation of the record entries of the frame, said deriving steps being effective to correct for any misregistration between the record entries and the detector elements.

2. A method according to claim 1 further characterized in that the array of detector elements is of substantially greater span than each record frame.

3. A method according to claim 1 or 2 further characterized in that said record entries and the array of detector elements are equispaced in respective linear arrays.

4. A method according to claim 1 further characterized in that the array of detector elements is defined by one or more detectors which are arranged to observe successive spatial positions at which they form transitory detector elements.

5. A method according to claim 1, 2 or 3 further characterized in that the detector elements comprise segments of a continuous linear detector arranged so that the values observed by each segment can be output separately from the values observed by other segments.

6. A method according to any one of claims 1 to 4 further characterized in that outputs from successively positioned detector elements are successively presented at regular intervals, and in that said modified values, while being restricted to values representing only said possible values, are produced at times which vary from the times of presentation of the detector element outputs in a way which reflects the magnitudes of the detector outputs.

7. A method according to claim 6 further characterized in that the variation in the time of transition from each modified value to the next, with reference to the presentation of the related detector element outputs, is proportional to the difference between these outputs and predefined levels.

8. A method according to claim 7 further characterized in that said possible values are the binary numbers 1 and 0, transitions from 1 to 0 are delayed in proportion to the difference between the leading detector element output and that corresponding to a 0, and transitions from 0 to 1 are delayed in proportion to the difference between the leading detector element output and that corresponding to a 1.

9. A method according to any one of claims 1 to 4 further characterized in that the possible values are the binary numbers 1 and 0, the centre-to-centre spacing between detector elements and between record entries, as presented to the detector elements, is equal and uniform, and in that the set of modified values is derived in part by serially carrying finite observed values less than a prescribed first threshold, itself substantially less than the observed value representing the possible value 1, for addition to respective, serially ordered, other observed values such that the resultant summations exceed said first threshold, but subject to each carried value not exceeding the observed value to which it is added by an amount greater than a second threshold.

10. A method according to claim 3 further characterized in that there are two or more detector elements in sub-arrays of uniform configuration per record entry, and in that the set of modified values is derived by ignoring observed values for detector elements at one or more corresponding positions in all the sub-arrays, when a predetermined proportion of such elements give observed values sufficiently different from those corresponding to said possible values.

11. A method according to claim 10 where said possible values are the binary numbers 0 and 1.

12. A method according to claim 3 further characterized in that detector outputs are presented sequentially at regular intervals according to their position in the linear array, that the number of detector elements per record entry is greater than 1 and may or may not be a whole number, and that the derivation from the continuously variable signal available from each detector element to that representing a possible value is achieved by sampling the detector output at times which depend on that output, and by determining the possible value to be that represented by the possible value closest to the detector output being observed.

13. A method according to claim 1, 2 or 3 further characterized in that the possible values are the binary numbers 1 and 0, the detector elements are an integral multiple n, including n = 1, of the record entries, and in that the set of modified values is derived by effecting small changes of the apparent positions of the record entries relative to the array of detector elements.

14. A method according to claim 13 further characterized in that the record entries are arranged in the medium such that their apparent positions relative to the array of detector elements may vary along the array.

15. A method according to any one of claims 1 to 5 further characterized in that the states and/or output of the detector elements are read serially so as effectively to produce a time-based analogue signal comprising said set of observed values, and in that said modified values are derived therefrom by analysis of said analogue signal.

16. A method according to claim 15 further characterized by extracting, from said analogue signal, a set of modified values corresponding to the binary numbers 1 and 0, by use of digital communications circuitry.

17. A method according to any one of claims 6 to 8, 12, 15 and 16 further characterized in that said derivation of the modified values is effected by employing a universal asynchronous receiver/transmitter (UART).

18. A method according to claim 15, 16 or 17 further characterized in that successive small segments of a continuous linear detector are read by directing a wave along the detector whereby to develop a moving conductive window between the detector and a more conductive layer which serves to transport the signal to the output.

19. A method according to claim 18 further characterized in that the wave is propagated in a material such as piezo-electric material which generates

a voltage in response to the wave ,which voltage, when applied to the gate of a continuous layer of Field-effect transistor material, opens the moving conductive window.

20. A method according to any preceding claim further characterized in that the record entries are optically scannable zones of variable or varying opacity.

21. A method according to claim 20 further characterized in that the medium is photographic film in microfiche format.

22. A method according to any preceding claim further characterized in that said marker pattern(s) are unable to be replicated in the data and identify the start and/or end of the respective frames, and in that the marker pattern(s) are utilised to assign positions and hence significance to the record entries independently of the detector element(s) used to observe them.

23. A method according to claim 22 where the possible values are the binary numbers 1 and 0, further characterized in that data bits derived from the observed values are stored in an electronic shift register, and shifted until the known patterns fall in certain bit positions connected to a binary identification circuit.

24. A method according to claim 23 further characterized in that the states and/or output of the detector elements are read serially, data bits(1 and 0) derived from the observed values are moved into a shift register serially, and complete data extraction occurs when the marker pattern reaches the part of the shift register connected to the binary identification circuit.

25. A method according to claim 22 where the possible values are the binary numbers 1 and 0, further characterized in that the states and/or output of the detector elements are read serially, data bits (1 and 0) derived from the observed values are entered into a detection circuit which blocks data from the system attempting to acquire the data until one or more of the known patterns is detected.

26. A method according to any one of claims 22 to 25 further characterized by mechanically moving the detector elements relative to the medium in response to failure to detect the known pattern(s) or failure to observe a predetermined number of data bits before or after the known pattern(s).

27. A method according to any preceding claim further characterized in that the frames are scanned in turn by relatively selectively moving the array of detector elements over the medium, in either or both of two mutually perpendicular directions as required.

28. A method according to any one of claims 1 to 27 where the record entries are optically scannable, further characterized in that the frames are scanned in turn by rotating a mirror disposed in an optical system between the frames and the array of detector elements.

29. Apparatus for carrying out the method of any preceding claim characterized by a holder to temporarily support or retain said medium; a substantially known array of detector elements moveable relative to said holder; means to scan each frame in turn with said array such that each record entry influences the state and/or output of at least one detector element, to produce a first set of observed values for each frame represented by the state and/or outputs of the detector elements; and means for utilising the limitations on the range of said possible values to derive from the observed values for each frame a set of modified values including recording entries of the frame, identifying one or more market patterns among the modified values, and utilising the marker pattern to derive from said modified values, an accurate representation of the record entries of the frame, said deriving means being effective to correct for any misregistration between the record entries and the detector elements.

30. Apparatus according to claim 29 further characterized in that the detector elements are disposed at equispaced intervals in a linear array.

31. Apparatus according to claim 18 further characterized in that the detector elements comprise segments of a continuous linear detector arranged so that the values observed by each segment can be output separately from the values observed by other segments.

32. Apparatus according to claim 29, 30 or 31 further characterized in that said scanning means includes a drive arranged to selectively relatively move the array over the medium in either or both of two mutually perpendicular directions, preferably such that these directions are parallel to the record frames and parallel to the channels of said medium.

33. Apparatus according to claim 32 further characterized in that the drive is arranged to relatively move the array at substantially constant velocity parallel to the channels and perpendicular to the frames, but stepwise parallel to the frames and perpendicular to the channels.

34. Apparatus according to claim 29, 30 or 31 for optically observing record entries, further characterised in that the scanning means includes a cylindrically curved mirror disposed so that the record frame of a medium in said holder lies on the face of the mirror and a further mirror mounted substantially at the axis of curvature of the cylindrical mirror for rotation about an axis parallel to said axis of curvature, whereby optical paths are successively provided between the record frames of a channel and the array of detector elements.

35. Apparatus according to claim 29, 30 or 31 for optically observing record entries, further characterized in that the scanning means includes a spherical or paraboloidal concave mirror or convex lens disposed to face the record frames of a medium in said holder, and a further smaller mirror mounted substantially at the focus of said concave mirror for rotation about at least one axis, whereby optical paths are successively provided between the record frames of a channel and the array of detector elements.

36. Apparatus according to any one of claims 29 to 35 further characterized by a semiconductor device comprising a Field-effect transistor layer which has one major face in electrically conductive contact with the detector elements and another major face in electrically conductive contact with a juxtaposed conductor layer,and a strip of material in proximity to the gate of the Field-effect transistor layer selected whereby on propagation of a wave in said material a voltage is generated which opens a moving conduction window in the Field-effect transistor layer.

37. A semiconductor device comprising a Field-effect transistor layer which has one major face in electrically conductive contact with a photoelectric or magneto-electric layer and another major face in electrically conductive contact with a juxtaposed conductor layer, and a strip of material in proximity to the gate of the Field-effect tansistor layer selected whereby on propagation of a wave in said material a voltage is generated which opens a moving conduction window in the Field-effect transistor layer.

38. A method according to any one of claims 6 to 8, 12 and 15 to 19 further characterized in that the clock frequency determining the rate at which the detector elements are serially read or at which modified values are extracted is arranged to be adjustable in response to physical expansion or contraction of said medium as observed by the detector elements, whereby to compensate for such expansion or contraction.

39. A method according to any one of claims 6 to 8, 12 and 15 to 19 further characterized by the use of clocking information in the data to generate correct clock frequencies despite any expansion or contraction of the medium as observed by the detector elements.

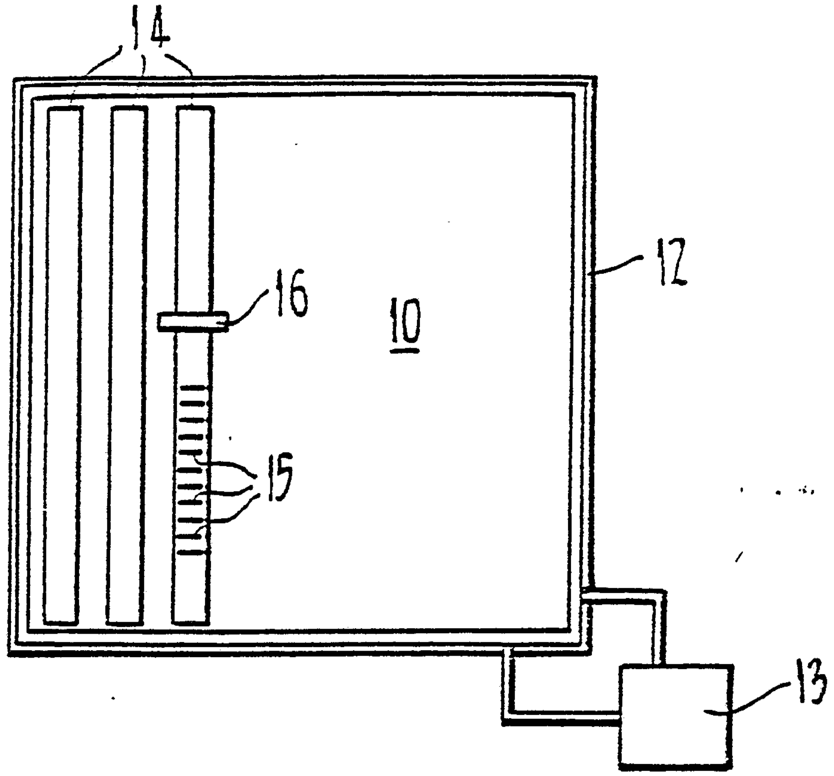


FIG. 1.

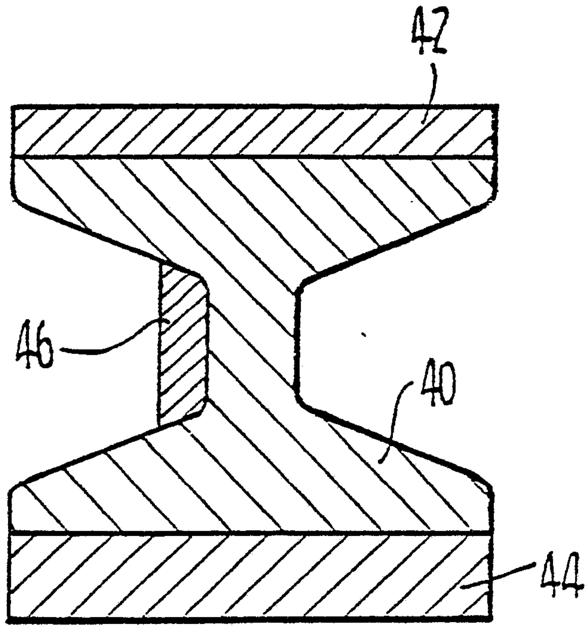


FIG. 5.

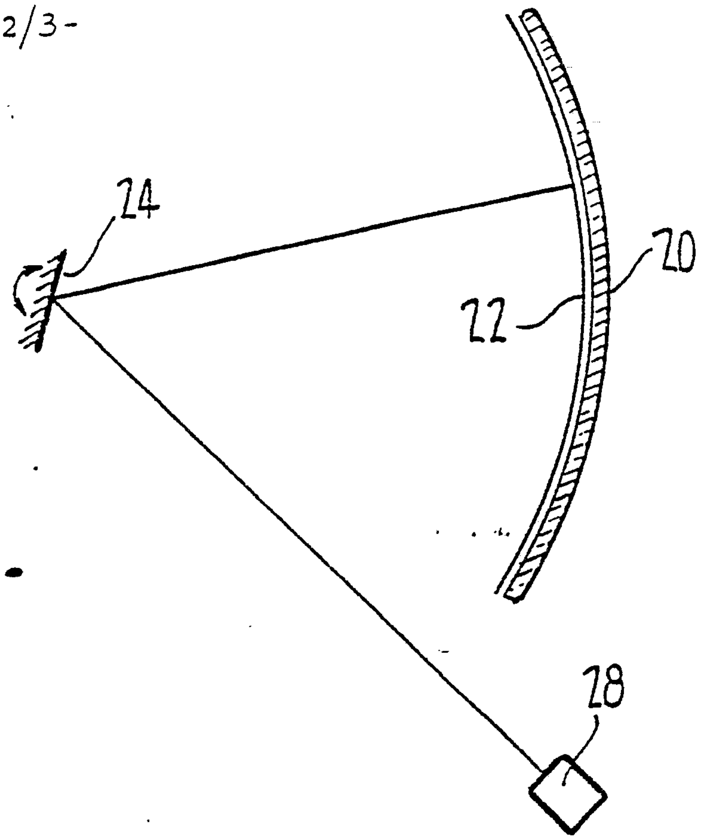


FIG. 2.

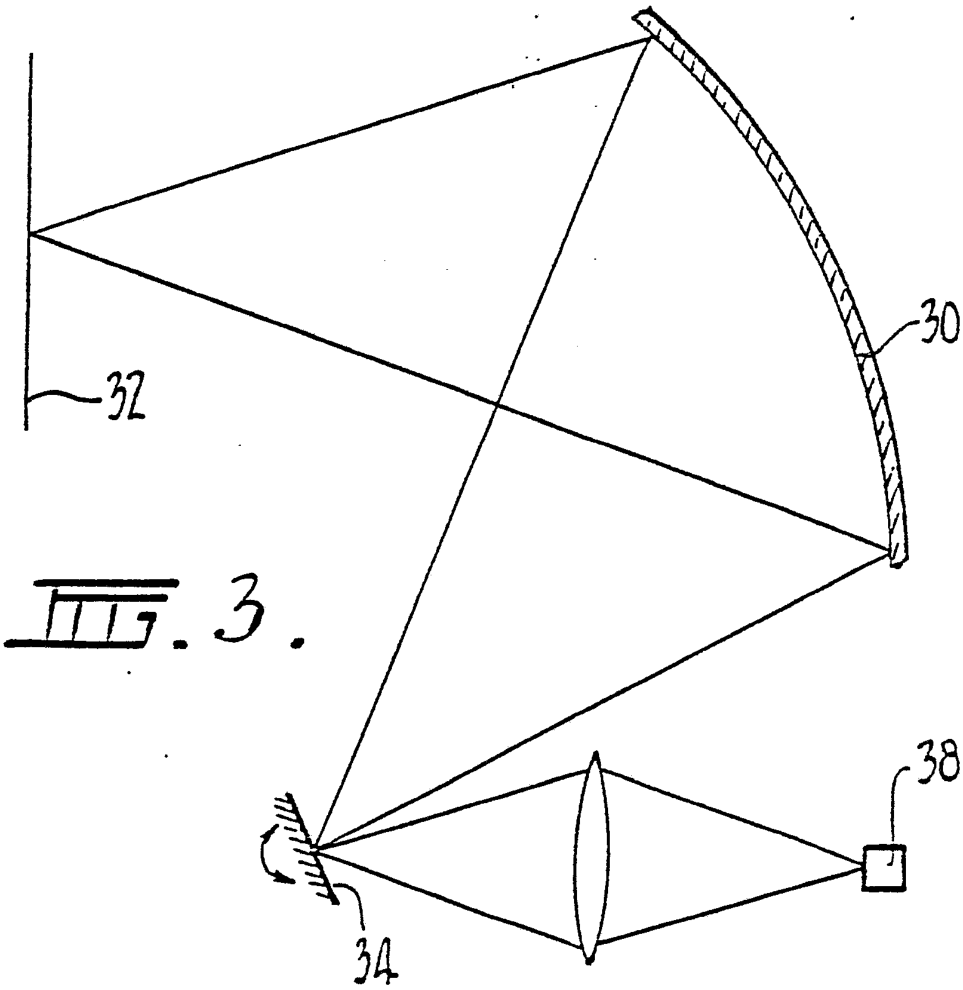
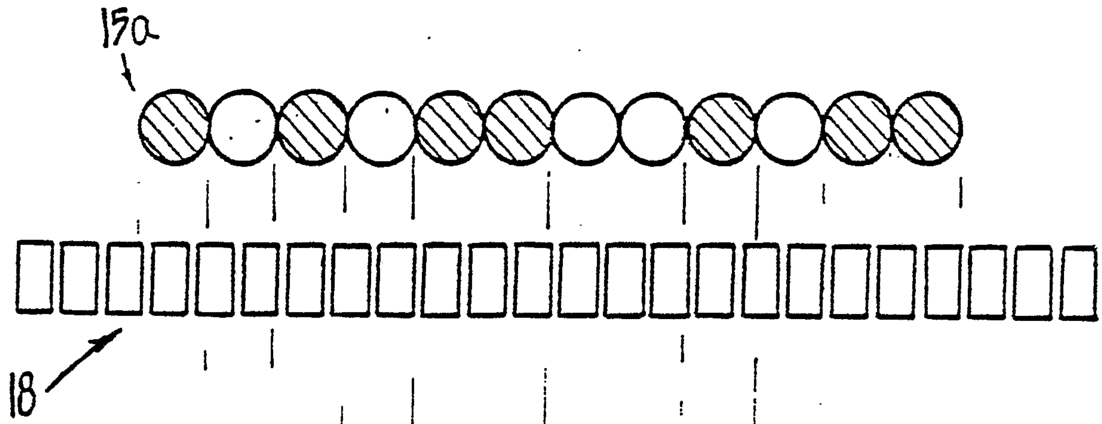


FIG. 3.

FIG. 4A.



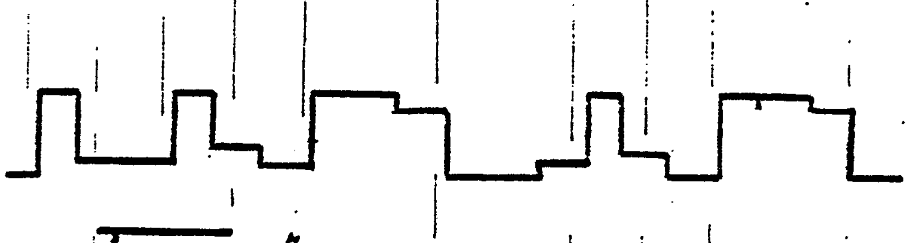


FIG. 4B.

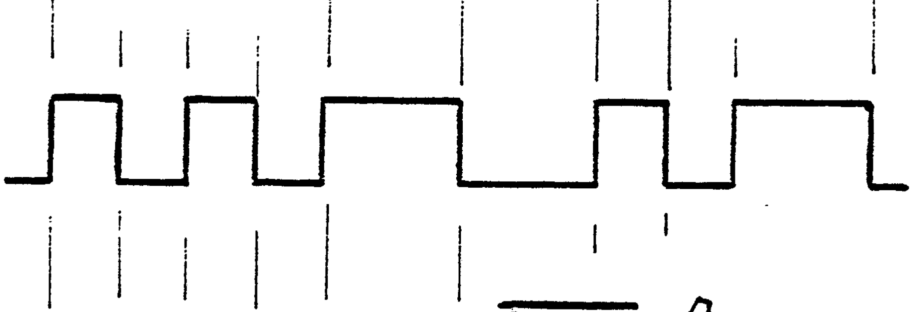


FIG. 4C.

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 81/00188

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

Int. Cl.[3] G06K 9/00, 9/62, 7/00, H01L 29/76, 31/08

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC	G06K 9/08, 9/62, 7/00
US Cl.	371/6, 371/42, 371/46, 340/146.3F, 340/146.3H

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

AU: IPC as above and G06K 7/015, 9/08; Australian Classification ~~54.4141~~

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]
A	AU, B, 27588/57 (222388) (INTERNATIONAL COMPUTERS AND TABULATORS LIMITED) 7 November 1957 (07.11.57)	
A	US, A, 3727183 (LEMAY) 10 April 1973 (10.04.73) (& DE, B, 1774672)	
A	US, A, 4228468 (HUMIKAZU NAGANO, et al) 14 October 1980 (14.10.80) (& JP, A, 54037626)	

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
17 February 1982 (17.02.82)	22 February 1982 (22.02.82)
International Searching Authority [1]	**Signature of Authorized Officer** [10]
Australian Patent Office	R. J. SAWYER

International Application No. PCT/AU81/00188

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers ______, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers ______, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

Claims 1 to 36, 38 and 39 define a method or an apparatus for reading stored information.
Claim 37 defines a semiconductor device.

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Claims 1 to 36, 38 and 39.

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.