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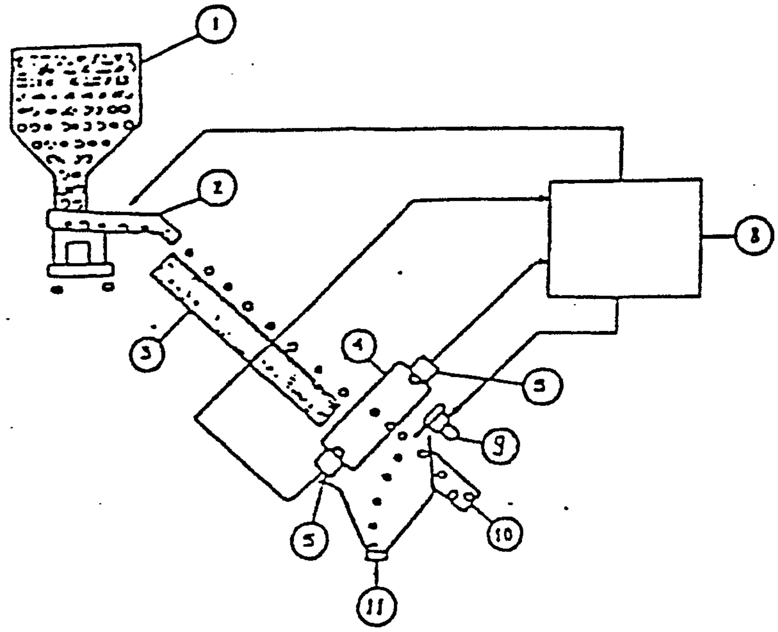
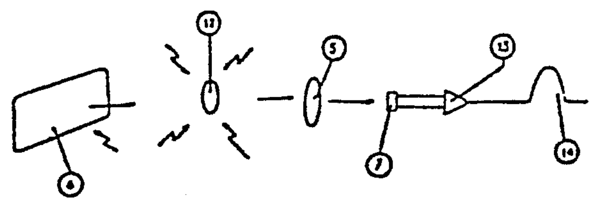
(54) Color sorting apparatus.

(57) An apparatus for sorting objects by color, such as coffee beans, peanuts, beans and other small granular objects. The apparatus includes a means of conveying the objects, uniformly and individually, to the interior of an illuminated analysis chamber that contains one or more sorting channels. Each sorting channel contains at least one lens group connected to photodetectors. The photodetectors are interconnected to electronic circuitry capable of transforming light reflected, transmitted or emitted by the objects into analog electrical signals that are digitized through electrical level detectors. Color analysis of the objects is based on a matrix sorting process that identifies color by comparing the above digitized electrical signals to the contents of a sorting matrix. There is also a matrix apparatus that allows the operator to select, modify, create and display the sorting matriz. There is a means of automatically generating the sorting matrix based on a sampling of electrical signals produced by passing a group of objects with specific color characteristics through the analysis chamber. Microprocessors in a process controller operating on real time are utilized. Adopting the matrix sorting process, this controller classifies objects as acceptable or unacceptable, as well as controlling and supervising all electronic apparatuses linked to the photodetectors. The process controller operates in every sorting channel so as to ensure that article sorting will be based on the matrix process and the sorting matrix.

EP 0 342 354 A2

Fig. 1





COLOR SORTING APPARATUS

This invention pertains to apparatuses for sorting objects, more particularly, an apparatus for sorting objects by color. This includes a means of conveying the objects, uniformly and individually, to the interior of an illuminated analysis chamber connected to electronic photodetectors and circuitry that can transform light reflected, transmitted or emitted by the objects into electrical signals. Also included are apparatuses that use a matrix sorting process to read the color of the objects by comparing these electrical signals to a sorting matrix, one that can be selected, modified or created by the operator by utilizing a matrix sorting apparatus, or it can be automatically generated by this apparatus based on a sampling of electrical signals resulting from passing a group of objects with specific color characteristics through the analysis chamber.

For monochromatic or bichromatic sorting apparatuses that utilize prior technologies for creating a sorting standard, said standard can be created by the operator through the preparation of a masking sheet, usually made of cardboard, placed over the face of a cathode ray tube. This is the process employed in model B-450 bichromatic sorting apparatuses, manufactured by Mandrel Industries Inc. (Houston, Texas). Prior to 1968, these apparatuses used a masking sheet over the face of a cathode ray tube (CRT) to distinguish between groups of acceptable and nonacceptable objects, using two electrical signals corresponding to two lengths of a light wave reflected by the object being examined. These signals were beamed onto the face of the CRT so as to define points in the cartesian coordinate system that would or would not be covered by the mask, thereby classifying the objects as acceptable or nonacceptable. With other sorting models (GB 100, GB 101) manufactured by Mandrel -- the company is now called Geosource Inc. -- the factory-made "sorting mask" was in the shape of a block, or "pattern", containing resistors that electronically defined straight lines in each quadrant of the cartesian plane, although it could not be modified or created by the operator. In later models made by Geosource Inc. (GB 104), the "pattern" resistors have been replaced by potentiometers, allowing the operator to control the straight lines that define the "sorting mask," although this is limited to lines pertaining to each of the four quadrants in the cartesian plane. This version with potentiometers has been the one adopted, almost simultaneously, by other manufacturers of electronic sorters. The latest Geosource model, the "UNISORT", is a bichromatic sorter that contains so-called "quickset pattern" apparatuses. These create a pattern based on a sampling of electronic signals generated by the passage of a selected number of objects. As before, the operator cannot modify the pattern in order to optimize the sorting process, except by the passage of another group of selected objects. In short, monochromatic or bichromatic sorters based on prior technology are extremely limited for the operator, in terms of creating, modifying and memorizing the sorting matrix.

Based on this invention, the sorting apparatus can have multiple channels that may or may not share a single analysis chamber. Color analysis of the object can be monochromatic, bichromatic or polychromatic, depending on the breakdown of the color spectrum for the light utilized in defining the color in order to obtain electrical signals.

Based on this invention, the sorting apparatus utilizes a MATRIX SORTING PROCESS that analyzes the color of the object by comparing electrical signals with the contents of a sorting matrix linked to the colors of the objects to be analyzed.

Based on this invention, the sorting apparatus utilizes a MATRIX SORTING APPARATUS that permits the creation, editing, modification and visualization of sorting matrixes, as well as the visualization, freezing and memorizing of electrical signals.

Based on this invention, the sorting apparatus contains an AUTOMATIC MATRIX APPARATUS capable of generating a sorting matrix from the electrical signals prroduced by the analysis of a group of objects with specific color characteristics, in addition to other innovations referred to below.

Before dealing with principles, processes and main components of the sorting apparatus in question, as an aid to comprehension a description will be given of a conventional bichromatic grain sorter, as shown in figures 1, 2, 3 and 4. This description will show the operation for each sorting channel and the sorting process for bichromatic grain analysis. It should be understood that the process is essentially applicable to any number of channels for sorting any type of object, through monochromatic, bichromatic, trichromatic or polychromatic means.

Figure 1 in the annex illustrates the basic principles of a grain sorting apparatus, whereby grains to be sorted are placed in a hopper (1), generally in the upper part of the apparatus, from which they are removed by an electromagnetic vibrator (2) that serves to convey them to an acceleration and alignment system (3) in the form of troughs, rotary cylinders or conveyor belts. This system feeds the grains at a speed of 2-4 m/s into an analysis chamber with suitable light for carrying out chromatic analysis of the grains. A lens apparatus, consisting of lenses and light filters (5), projects the image of the grain onto the face of a photocell (7) -- in a monochromatic analysis -- or two photocells after breaking the beam of incident light rays down into two parts of the color spectrum (bichromatic analysis). The electrical signal from each photocell is the result of comparing grain color to a reference color, generally a painted plate referred to as a contrast or reference background (6), or else an electrical level corresponding to a color reference. The signal from each photocell must be amplified suffiqiently to allow it to be processed by electronic control apparatuses (8). Once the signals are processed, the electronic control apparatus sends a command pulse to the ejector valve so as deflect any nondesirable grains by a blast of compressed air lasting from 1-2 msecs. The ejector valves (9) are of the electropneumatic type with electroelectronic control and are usually located underneath the analysis chamber. As a result of the process, acceptable grains are gathered by the selected-grain collector tube (10). Unwanted grains are gathered by the rejected-grain receiver (11) once they have been deflected by the ejector valve (9).

Figure 2 shows the lense apparatus (19) that handles the light from a bichromatic sorter so as to obtain signals Y and X, highlighting the object being analyzed (12), the lens subgroup (5) that receives the beam of light reflected from the grain, and the light beams (17 and 18) that strike the photocells (7) that convert light into electrical signals Y and X. It should be noted that the light beam can be broken down by means of dichroic filters, semi-mirrored surfaces and color filters, or by a T or Y-shaped optic fiber cable, a description of which can be found in specialized literature and thus forms part of the current state of the technique. In the specific instance of the bichromatic analysis of grain color, light arriving at the lens group is broken down into two bands within the color spectrum, generally CYAN and RED. Other bands from the spectrum may also be chosen based on the project or the characteristics of the grains to be sorted, or else on the basis of the color characteristics of the light source. The light reflected from the grain is therefore continuously captured by the two photocells and the electrical signals resulting from photocell action will be directly related to the grain color. These signals will henceforth be referred to as Y and X and will represent grain color, broken down into the cyan and red light bands by bichromtic analysis. Each pair of photocells and the lens group linked to them is usually labeled as a "bichromatic view." Each sorting channel can have as many views as necessary, although 2 or 3 bichromatic views are normally utilized in each channel of the sorting apparatus.

Figure 3 is a block diagram of the electronic part of a bichromatic sorting apparatus with two lenses for examining the grain from both sides and two sorting channels that operate independently. A line (20) divides the figure into two parts, one corresponding to the first sorting channel and one to the second channel. This figure also shows the photodetectors (7), amplifiers (13), and electrical signals (14) obtained by the photodetectors linked to the amplifiers and corresponding to the light related signals reflected from the grains (12). These signals are identified by Y and X for each pair of photodetectors (7) pertaining to a lens (19), by A and B for each lens pertaining to each channel, and lastly, by 1 and 2 for each sorting channel. The signal YA1 thus indicates the color cyan and XA1 indicates red in the light beam striking lens A for channel 1. In the arrangement shown in figure 3, each grain passing through channel 1 produces signals YA1 and XA1 by means of lens A, which examines the grain from one side, and signals YB1 and XB1 by means of lens B, which examines the grain from the other side. Figure 3 also shows the block (8) corresponding to the electronic circuitry that analyzes grain color by means of signals Y and X; following analysis, they provide the detection signals (15 and 16) for the unwanted color, seen through lenses A and B. Finally, block 21 shows the elements common to both channels, such as the power unit, feed supplies and other subgroups that are not described here owing to their simplicity and the fact that they are not part of this invention.

Figure 4 is a cartesian representation of the analog electrical signals Y and X in a plane in which the area of the acceptable grains is bounded by straight lines in each of the quadrants and the area of the unacceptable grains corresponds to the part of the plane outside of the acceptable-grain area. The lines setting off these areas are electronically defined in sorting apparatuses that use prior sorting technology.

Figure 5 is a simplified illustration of one way to obtain a digitalized electrical signal by means of detectors with adjustable levels that have been linearly staggered.

Figure 6 shows the results of the nonbinary digitizing of two signals, "X" and "Y" pertaining to a bichromatic view.

Figure 7 shows the basic layout of the matrix panel with LEDs and certain command keys on the main panel.

Figure 8 is a schematic diagram of the matrix panel with a typical sorting matrix.

Figure 9 shows a main-panel LED, the light-conducting cable and one version of the electronic circuitry that makes it possible to change the state of the luminous element on the matrix panel.

Figure 10 shows block diagrams for the electronic element referring to signal processing and process control.

Based on this invention, one of the principles of the sorting process is to create a digital sorting matrix in two or more dimensions, depending on whether grain color is analyzed bichromatically or polychromatically. This sorting matrix contains geometric acceptance and rejection areas that are no longer bounded merely by straight lines; instead, these areas can assume any shape, being defined by points whose contents are "0" or "1", which define points that are characteristic of "0" or "1" type colors.

Based on this invention, the MATRIX SORTING PROCESS for the sorting apparatus utilizes digitized electrical signals grouped in the form of variables that define characteristic points of the color of the area of the object analyzed and compares these points to those in each geometric place contained in the sorting matrix. Each characteristic point of the color can be formed by one, two, three or more electrical signals depending only on the number of signals into which light data from the object has been changed by the photocells in the analysis chamber and the electronic circuitry linked to the sorting equipment. In other words, based on the invention process applications are not limited to monochromatic or bichromatic sorters but rather can be applied to any apparatus for sorting objects by color utilizing any number of signals for determining the color of the objects examined.

The sorting matrix utilized in the object-sorting process, based on this invention, may contain as many geometric places as the process requires, since each place contains the characteristic points of the color of a specific group of objects. Each sorting matrix point can be defined by as many coordinates as there are electrical signals defining the color of the object. The geometric place for the characteristic points of the color for a specific group of objects may assume any shape, meaning that it can assume shapes different from those utilized in sorters with prior technology.

Based on this invention, sorting matrixes can be supplied with the sorting apparatus so that the operator may chose the one most suitable. Or they may be created by the operator and memorized by electronic apparatuses in the sorter, or they may be generated by copying and editing that utilizes the matrixes memorized by the sorting apparatus.

Based on this invention, sorting matrixes can also be generated by apparatuses within the sorter through sampling of the electrical signals obtained when a group of objects with specific color characteristics is passed through the analysis chamber. Such signals are related to the light reflected, emitted or transmitted by the group of objects. Furthermore, the matrix generated by this process can also be copied and modified by the operator so as to optimize the sorting process.

Based on this invention, a basic characteristic of the sorting process is that the operator may easily and intuitively choose, create, edit, modify and memorize the sorting matrix by means of elelctronic apparatuses.

Based on this invention and while maintaining its general nature, the sorting process is particularly applicable to bichromatic grain sorting that makes use of light reflected by the grain, broken down into two bands in the color spectrum, with two signals corresponding to these bands obtained by means of electronic photodetectors and amplifiers. Owing to their source, these signals distinguish the color of the grain. Through the sorting process as seen in this invention, these signals are arranged in the shape of two variables, X and Y, which are compared to a sorting matrix represented in the cartesian plane by the H (horizontal) and V (vertical) axes. This matrix contains the parameters needed to define the geometric place or places for the grain groups to be sorted, while the result of the comparison will determine the color group to which the grain belongs. The grain will consequently be accepted or rejected in the sorting process, depending on the programming previously established.

The objectives, advantages and other aspects of this invention can be more easily understood from the following description. While maintaining its general nature, the invention is based on the grain sorting process by means of a bichromatic channel, although it is applicable to any number of monochromatic, bichromatic or polychromatic channels for analyzing any type of object.

As an aid to understanding, the electronic signals that distinguish grain color bichromatically will henceforth be labeled "X" and "Y", which may correspond to the RED and CYAN content of the light reflected by the grain or to any other pair of bands in the color spectrum that conforms to the bichromatic analysis process.

With modern equipment, data is normally processed digitally and controlled by microprocessors for a number of reasons. These include processing speed, accuracy, and ease of memorization, in addition to obtaining the best cost-benefit ratio when all resources proceeding from a process-control program are considered. As for the PROCESS and MATRIX SORTING APPARATUS for objects based on color, as well as for the AUTOMATIC MATRIX APPARATUS utilized in the sorting apparatus this invention entails, we will assume that electronic signals will be treated digitally and submitted to real-time control by microprocessors, although this is not the only way to utilize the process.

Without detracting from its general nature, Figure A below, represented by "0" and "1", is a cartesian representation in the H-V plane of a bichromatic sorting matrix that contains 64 points in each of its quadrants and 32 points on the H and V axes, besides its origin. The number of points contained in the matrix can be more or less than that chosen for the case and will basically depend on the resolution desired for defining the matrix.

In accordance with the principles of bichromatism, we can break down the light spectrum into two color bands. These can be red-cyan, yellow-blue, magenta-green or any other combination suitable for sorting. As a hypothetical case and without detracting from its general nature, let us suppose that we associate red and cyan with the H and V axes, respectively, in the representative plane of the matrix. The point where the axes cross (origin) will represent a reference for both the red and cyan. Based on these initial considerations, we can associate the points farthest from the origin, from the first to the fourth quadrant, with light/white (maximum H and V), cyan (minimum H and maximum V), dark/black (minimum H and V) and red (maximum H and minimum V). The remaining colors, in terms of hue and intensity, will be distributed throughout the four quadrants and axes. For the right (positive), the H axis, seen from the reference point, will represent those colors with a red content lower than the amount of red used as a reference, and for the left, those with a red content higher than this amount. By the same token, the V axis, counting upwards and downwards from the reference point, will represent those colors with a higher and lower cyan content.

As shown in Fig. A, points are identified by "0" and "1", which can be linked to the geometric place for points with color characteristic "0" and the place for points with color characteristic "1".

```
                                 V
                                 :
                                 :
      1  1  1  1  1  1  1  1  1  1  1  1  0  1  1  1  1
      1  1  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1
      1  1  1  1  1  1  1  1  1  0  0  0  0  0  1  1  1
      1  1  1  1  1  1  1  0  0  0  0  0  0  1  1  1  1
      1  1  1  1  1  0  0  0  0  0  0  0  1  1  1  1  1
      1  1  1  1  1  0  0  0  0  0  0  1  1  1  1  1  1  -  (V=+3)-
      1  1  1  1  0  0  0  0  0  1  1  1  1  1  1  1  0  -  (V=+2)-
      1  1  0  0  0  0  0  1  1  1  1  1  1  1  1  0  0  -  (V=+1)-
   >--1  0  0  0  0  0  0  0  *  0  0  0  0  0  0  0  0  ----------H--->
      1  1  0  0  0  0  0  0  1  1  1  1  1  1  1  0  0
      1  1  1  0  0  0  0  0  0  0  1  1  1  1  1  1  0  -  (V=-2)-
      1  1  1  1  0  0  0  0  0  0  0  1  1  1  1  1  1
      1  1  1  1  1  0  0  0  0  0  0  0  1  1  1  1  1  -  (V=-4)-
      1  1  1  1  1  1  1  0  0  0  0  0  0  1  1  1  1
      1  1  1  1  1  1  1  1  1  0  0  0  0  0  1  1  1
      1  1  1  1  1  1  1  1  1  1  1  0  0  0  1  1  1
      1  1  1  1  1  1  1  1  1  1  1  1  0  1  1  1  1
                                 :
                                 :
                                 ^
```

Figure A - Cartesian representation of a bichromatic sorting matrix

The process for addressing and storing the contents of the above matrix in the digital working memory is as follows:

1) The address can begin with 00010001 00000001;

2) The eight most significant address bits can define each quadrant and each of the four semi-axes "H" and "V";

3) The eight least significant address bits can define the ordinate for points inside each quadrant;

4) The eight least significant address bits can always be "0" for the four semi-axes.

5) The contents of each address relative to the quadrants can contain color characteristic "0" or "1" for each point defined by the ordinate;

6) The contents of each address relative to each of the four semi-axes can contain color characteristic "0" or "1" for each point on the four semi-axes "H" and "V";

7) Initial addressing for different sorting matrixes can be defined by the eight most significant address bits, except for those addresses committed to the four quadrants and four semi-axes.

```
- addressing - content - observations:

00010001 00000001 00111111 => line (V=+1) : 1st quad.
00010001 00000011 01111111 => line (V=+2) : 1st quad.
00010001 00000111 11111100 => line (V=+3) : 1st quad.
00010010 00000001 11000001 => line (V=+1) : 2nd quad.
00010010 00000011 11110000 => line (V=+2) : 2nd quad.
00010010 00000111 11111000 => line (V=+3) : 2nd quad.
00010011 00000011 11100000 => line (V=-2_ : 3rd quad.
00010100 00001111 11111000 => line (V=-4) : 4th quad.
00010101 00000000 00000000 => semi-axis "+H"
00010110 00000000 11100001 => semi-axis "+V"
00010111 00000000 10000000 => semi-axis "-H"
00011000 00000000 11100001 => semi-axix "-V"
```

Observations regarding the sample addressing and contents of the points on ordinate V= +3 in the first quadrant:

1) ADDRESS => 00010001 00000111 (the 3 least significant bits are 111 since we are referring to the third line of points beginning with the H-axis);

2) CONTENTS => 11111100 (the 2 least significant bits are 00 since they refer to color "0" and the others refer to color "1"). The least significant bits are those that refer to the points closest to the axes, with each point linked to one and only one bit.

The creation of the address and contents of each point in the above example does not obey conventional criteria for binary structures and is one of the objects of this invention. Other ways of addressing and identifying the contents, including conventional digital methods, are also valid without detriment to the principles of this process. In addition to the structural innovation, the above method adopted offers advantages in regard to the quantity of bytes needed for storing matrix contents, as well as increased access speed to point contents.

In regard to electrical signals X and Y, representing the pair of color-spectrum bands that distinguish grain colour in bichromatic sorting, we shall consider X as standing for red and Y for cyan, so that the color pair will be consistent with the sorting matrix.

There are countless ways to digitize X and Y signals. In regard to this invention, however, a nonconventional way will be described, one that cuts costs and increases processing speed. It should be noted that although we refer to a specific digitizing method, this does not mean that other ways cannot be used, providing that the processing principles of this invention are upheld.

Returning to the example of the sorting matrix, we can see that there are eight points on each of the semi-axes H and V, counting from the origin, for the positive as well as negative side. For this type of matrix, signals X and Y will be digitized on eight positive levels and eight negative levels, based on an electrical reference level. Should the matrix be structured with sixteen points on each of the positive and negative semi-axes, electrical signals will be digitized on sixteen positive and sixteen negative levels. In our example, we consider only the matrix structure with eight points on each of the positive and negative semi-axes.

By way of an example of digitizing the bichromatic signals X and Y, we shall consider the hypothesis that these signals reach a maximum amplitude of eight positive and eight negative volts. In this case eight levels, one volt apart, will be used to describe the signals digitally. Moreover, simple logic will identify the cartesian plane region where each pair of electrical signals is found. Once these conditions are established, electrical signals will be digitized based on the following examples.

1) Locating the cartesian plane region:

X	Y	location	region address:
X>0	Y>0	=> first quadrant	=> 00010001
X<0	Y>0	=> second quadrant	=> 00010010
X<0	Y<0	=> third quadrant	=> 00010011
X>0	Y<0	=> fourth quadrant	=> 00010100
X>0	Y=0	=> positive semi-axis X	=> 00010101
X=0	Y>0	=> positive semi-axis Y	=> 00010110
X<0	Y=0	=> negative semi-axis X	=> 00010111
X=0	Y<0	=> negative semi-axis Y	=> 00011000

2) Examples of digitizing signals X and Y, utilizing amplitude region and modules:

	Y	X	region	digital Y	digital X
a)	+1 V	+1 V	00010001	00000001	00000001
b)	+2 V	+3 V	00010001	00000011	00000111
c)	+4 V	-3 V	00010010	00000001	00000111
d)	-2 V	-4 V	00010011	00000011	00001111
e)	-4 V	+2 V	00010100	00001111	00000011
f)	0 V	+5 V	00010101	00000000	00011111
g)	+3 V	0 V	00010110	00000111	00000000
h)	0 V	-8 V	00010111	00000000	11111111
i)	-5 V	0 V	00011000	00011111	00000000

As was previously shown, the sorting matriz can be stored in a digital working memory where addresses are established depending on the quadrant region and a point coordinate; each bit in the address contents corresponds to the color-data contents of a point. The contents of an eight-point line can therefore be stored in each address and the contents of a quadrant can be stored in each eight addresses. Thus, for 36 eight-bit memory positions the contents of a 256-point matrix can be stored in the quadrants, plus 32 points on the axes. It should be noted that this is not the only way to store the contents of a sorting matrix digitally, though it undoubtedly is an economical way to do so and is one of the objectives of this invention. Besides this economical aspect, the structure proposed for storing the matrix contents allows for an easy and quick comparison to color data contained in the electrical signals.

The process for comparing the color content of electrical signals to the matrix contents is based on the following:

1) For quadrants and the X axis, bytes in the region and the digital Y are used as an address and we compare the contents of this address, in the matrix working memory, to the digital X;

2) For the positive and negative Y semi-axes, bytes in the region and digital X are used as an address and we compare the contents of this address, in the matrix working memory, to the digital Y.

Based on the digitizing examples in item 2, page 14, for the signal Y= +1 and X= +1 (a) we will have the address 00010001 00000001, whose contents in the example of the sorting matrix (MATRIX A) are 00111111. When this is compared to the digital X byte, bit by bit through "E" logic, the result is "1", which means that signals X and Y in the example define a point in the geometric space for points with color characteristic "1". For all the examples, we will therefore have:

Y -	X -	address		-contents-	digital X-	"E" logic
+1	+1	00010001	00000001	00111111	00000001	"1"
+2	+1	00010001	00000011	01111111	00000111	"1"
+1	-3	0001010?	00000001	11000001	00000111	"1"
-2	-4	00010011	00000011	11100000	00001111	"0"
-4	+2	00010100	00001111	11111000	00000011	"0"
0	+5	00010101	00000000	00000000	00011111	"0"
+3	0	00010110	00000000	11100001	00000111	"1"
0	-8	00011000	00000000	10000000	10000000	"1"
-5	0	00011000	00000000	11100001	00011111	"1"

In the above examples, electrical signals representing grain color have been digitized in a nonconventional though rather simplified way, because the method utilized is based on the recognition of the cartesian plane region in which the point defined by the X and Y variable is found, as well as on the digitizing of the X and Y amplitude module by means of levels reached by the signals. The levels utilized in the examples are based on a maximum amplitude of eight volts, with one volt between levels. The value of the maximum level can actually be any one, provided that it is adapted to the signal amplitude; moreover, spacing need not be equal between levels. For practical purposes, these levels can be adjustable for allowing continuous control of color recognition related to the electrical signals. This continuous control may consist of a sensitivity adjustment that serves to increase or decrease the value at electrical signal levels. As an example, for a maximum level of eight volts with one volt between levels, a 4.5-volt signal would give a digitized value of 00001111 (4 levels); however, by boosting sensitivity it could be 00011111 (5 levels), and 00000111 (3 levels) if sensitivity is lowered. The same effect can be obtained with a potentiometer connected to the amplifier, which would make it possible to increase the signal from 4.5 to 5.0 volts, or attenuate it to 3.8 volts. In short, any process capable of increasing or reducing transformation at electrical signal levels can be utilized as a signal sensitivity adjustment.

Once the digital structuring method for the sorting matrix has been defined, along with the method for digitizing electrical signals that represent grain color and the creation of a means of digitally comparing points defined by the electrical signals to those contained in the sorting matrix, the each electrical signal can be identified as to whether it corresponds to a group of objects with color "0" o with color "1". Thus the objects can be sorted by means of rejecting those that produce color signal "0" or "1".

The sorting matrix can be created or changed by filling in the address contents, structured in keeping with this invention and utilizing any type of data-entry element. It can be memorized in any appropriate apparatus. Memorization apparatuses can store differing matrixes that have been selected for specific duties. Their structures are similar, with it only being necessary to correct the address when digitized signals are compared to the contents of the sorting matrix, or else copy the desired matrix into the working memory. In the latter case, working memory will always have the same address, with only the contents of these addresses varying in accordance with the memory to be utilized.

Based on this invention, the MATRIX APPARATUS used by the sorting apparatus consists of a DISPLAY ELEMENT capable of visualizing the contents of the sorting matrix and digitized electrical signals, a CONTROL ELEMENT capable of controlling changes in the contents of each matrix point, and a COUPLING ELEMENT that links the display and control elements to the sorting apparatus circuitry. Based on this invention, a feature of this apparatus is that it allows the operator to visualize, select, create, edit and modify the sorting matrix easily and intuitively.

Based on this invention and without detracting from its general nature, the apparatus is particularly applicable to bichromatic grain sorting that utilizes the light reflected by the grain, broken down into two color spectrum bands. This method uses electronic photodetectors and amplifiers to obtain signals that correspond to these bands, signals that distinguish grain color based on where they are generated. Utilizing the matrix sorting process, the signals are grouped into two variables, X and Y, which are compared to a sorting matrix represented in the cartesian plane by H (horizontal) and V (vertical) axes. This matrix contains the parameters needed to define the geometrical place or places for the grain groups to be sorted, and the result of the comparison will define the color group to which the grain belongs. Consequently, the grain may be accepted or rejected in accordance with programming previously established by using the sorting matrix.

Based on this invention, the DISPLAY ELEMENT must be capable of visually displaying the sorting matrix, meaning that it can show the operator a form similar to the following:

```
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O * O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
O O O O O O O O O O O O O O O O O
```

Figure B - Basic Form for Display Point Matrix

Note:

1) This matrix can be interpreted as being empty and ready for programming, or else as a matrix containing only those points with color characteristic "0".

2) The origin of the cartersian plane is found in the center of the matrix and serves to visualize matrix contents. This center may contain any symbol other than "0" and "1," or it may contain nothing.

3) The display element may be circular, rectangular or any other shape, provided that it can visually present the matrix in a shape similar the one above.

The display element may be a cathode ray tube, a liquid crystal display, a group of bulbs or any other device capable of showing the sorting matrix visually. As one of the most characteristic shapes of this invention, this element can be a group of LEDs arranged in the following way, in which "0" can be represented by an unlit LED and "1" by a lit one, thereby visually representing the sorting matrix.

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1
1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1
1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1
1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	0	0	*	0	0	0	0	0	1	1	1
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure C - Example of Matrix with LEDs

Note:

The display element may also be utilized for displaying electrical signals X and Y while grains are being examined, since digitized signals have a coding similar to that of the matrix. In addition, X and Y signals for each grain can be frozen and shown on the display, cumulatively or not, so as to locate the geometric place for a specific grain group.

Based on this invention, the CONTROL ELEMENT may be a keyboard with a sufficient number of keys and contacts for identifying each matrix point or line so that by operating the contacts it will be possible to give a command to shift from state "0" to state "1" and viceversa. One of these control forms could be a set of contacts with the shape of Fig. B and containing LEDs inside so that it would serve as both a display and control element. Another type of control element would be to use an optic fiber cable connected to a photodetector and a detection/simple-logic circuit. By placing one end of the cable on the LED whose state one wishes to change, a photodetector at the other end would recognize condition "0" or "1". This would produce the change in the definitive state by using a scanner system so as to confirm, LED by LED, which of them is transmitting the change-of-state condition to the photodetector through the optic fiber cable. The two latter forms are characteristic elements of this invention.

The COUPLING ELEMENT links the display and circuit-control elements associated with the memorization of the digital matrix so as to transmit matrix content data to the display element, receiving data from these elements regarding changes introduced in order to memorize the new matrix. This element functions as a data input-output apparatus within a routine to be explained below.

1) The memory contents that contain the matrix are sent to the display element following the sequence of addresses, which are arranged in the order of quadrants and semi-axes;

2) For an 8-bit system, the contents of each address correspond to an eight-point line in the display element and a point corresponds to each bit. The least significant bits show the contents of the points closest to the origin and the most significant ones show the points farthest away.

Note:

The coupling element can also be used for transmitting electrical signals X and Y to the display element while grains are being examined, since the digitized signals have a coding similar to that of the matrix. In addition, the X and Y signals for each grain can be memorized and displayed so as to locate the geometric place for a specific grain group.

By way of example, the following is the contents of some addresses beginning with the firrst, which will be the first line of the first quadrant:

location	contents	LED	obs.
quad. 1, line 1	11000000	00000011	Y = +1
quad. 1, line 2	10000000	00000001	Y = +2
....			
quad. 2, line 3	11111110	11111110	Y = +3
....			
quad. 3, line 3	11110000	11110000	Y = -3
....			
quad. 3, line 2	11110000	00001111	Y = -5
....			
semi-axis + X	11100000	00000111	Y = 0
semi-axis + Y	11110000	00001111	X = 0
semi-axis - X	11111100	11111100	Y = 0
semi-axis - Y	11000000	11000000	X = 0

Note:

LEDs with "0" should be considered as unlit and those with "1" as lit. To compare table data with display LEDs, all such data should consider LEDs as horizontal, except for LEDs for the Y semi-axes, which should be considered as vertical.

Based on this invention, the apparatus as described herein operates as an intelligent data input-output device, thereby fulfilling its objectives to create, display, edit and modify sorting matrixes.

Based on this invention, the purpose of the AUTOMATIC MATRIX APPARATUS is to automatically generate sorting matrixes based on electrical signals produced by the passage of a group of objects with specific color characteristics. So that the automatic matrix apparatus will operate correctly, it is necessary to execute a microprocessor control program based on the following principles.

The automatic sorting matrix can be automatically created by passing a series of objects pertaining to a specific color group through the analysis chamber. These objects must all be considered as acceptable within the standard sorting process. As the objects go through electrical signals representing the color of the objects are produced, which must undergo digitizing as described in this invention. By using a specific program for automatically creating a matrix -- also part of this invention -- one or more microprocessors will send the digitized electrical signals to an empty memory. This will follow the same digital structure of the matrix and of the comparison process involving the formation of addresses and their contents. This procedure results in a temporary matrix containing points characteristic of color "1". These points are significant because they correspond to those levels actually reached by the electric signals linked to the objects previously selected as belonging to a specific color group. Once the temporary matrix is memorized, the program for automatic matrix creation will examine the temporary matrix on the basis of a cartesian plane, so as to define the boundaries of the geometric place for points with color characteristic

"1". It will next proceed to inspect the temporary matrix, assigning a "1" to all points inside the boundary and a "0" to those outside. This is necessary because a quantity of objects is not an infinite number and therefore some points with a "0" content may accidentally exists inside the geometric place for points with "1".

The same program can generate and memorize an inverse matrix, changing the "1" contents for "0" and viceversa, so as to create a working matrix ready for operation. The larger the automatic matrix and the better prepared the previously chosen objects are, the better this matrix will be. The automatic matrix can be utilized, without changes, in the sorting of objects. If required, it can be changed by the matrix sorting apparatus so as to optimize the automatic sorting matrix.

The attached drawings will serve to identify the main apparatuses and to explain their function, as well as that of the matrix process, all of which characterizes the sorting apparatus based on this patent.

Figures 1, 2, 3 and 4, previously described, refer to the basic characteristics of a bichromatic sorting machine with prior technology; they therefore do not pertain to the present patent, serving only as informational material.

Figure 5, broken down into 5A and 5B, refers to the nonbinary digitizing method and apparatus for analog electrical signals, through the use of adjustable level detectors linearly staggered and connected to a sorting channel with two bichromatic views that detect the light from the objects, utilizing photodetectors to produce the pairs of electrical signals GA-RA (24), from view "A", and GB-RB (25), from view "B". Without detracting from the general nature, we shall consider signals G-R as referring to the cyan and red contents, respectively, of the object under analysis and captured by an analysis camera lens. Each electrical signal represents a color content for the article and may be more or less intense than an analog reference level while having the typical shape (27) shown in the drawing. So that there will not be a large number of positive and negative level detectors, and so that temporary digitizing and memorization can take place under the control and synchronization of microprocessors, signals must be properly processed. One way to do so is shown in Fig. 5A, whereby the electrical signal (27) passes through an analog rectifier circuit (28) at whose output a signal (29) appropriate for the multiplexer (30) is obtained. Signals G and R are also sent to a presence and polarity detector (31) so as to accurately determine when the object enters and leaves the analysis chamber and to verify in which quadrant or on which semi-axis of the cartesian plane the signal pairs GA-RA and GB-RB are located. Signals with a cyan content (33), red content (34) and presence/polarity (32) are obtained by sampling at the multiplexer output. So as to simultaneously digitize each pair of signals G-R, there is a set of level detectors for cyan and another for red, which will be detailed in Fig. 5B. In the case of eight-bit microprocessors, each set of level detectors can have up to eight detectors, which will have their outputs interconnected to logical units for temporary memorization with 3-state latch-buffer operation. As shown in Fig. 5A, there are eight detectors for the cyan sample signal (33) as well as for the red sample signal (34). At the input for collector logical circuitry, there is the digitized signal for cyan (35) and for red (36), both being eight bits. For identification of the quadrant and the cartesian semi-axis, there are signals G+, G-, R+ and R- (32) at the muliplexer output, which are sent to a latch-buffer circuit (40) in the form of a 4-bit signal. The channel microprocessor (41) synchronizes and controls the multiplexer (30) and the circuitry receiving the digitized electrical circuits (35, 36, 37) so that at the latch-buffer circuit outputs (38, 39, 40) signal pairs G-R are ready to be analyzed on the basis of the sorting matrix process.

Figure 5B provides an example of a circuit capable of generating linearly staggered and adjustable levels, which are applied in detectors used to digitize the electrical signals that characterize object color. The general sensitivity potentiometer (51) acts on the operational amplifier (57) so that its output (59) will vary linearly with changes in general sensitivity. Sensitivity levels S1, S2, ... S8 may show the same difference in potential among themselves provided that the resistors linked to these levels have the same value. Voltage at the S1 level, for example, depends on the output voltage (59 and 60) for each amplifier (57 and 58) connected to the opposite ends of the resistor network. The electrical potentials for the levels can also be subjected to a variation in discrete values by using a microprocessor (52) acting on a network of R/2R resistors (53) as if it were a digital-analog converter. In this example, four binary outputs on the microprocessor (52), acting on the resistor network (53), can apply up to sixteen different voltages to the inverter input (54) of the amplifier (55), depending on the binary number at the microprocessor output. At the output (56) of the amplifier (55) controlled by the microprocessor there will be a voltage variation inversely proportional to input variation. Output potential (56) for the amplifier (55), acting on the amplifiers (57 and 58) linked to the ends (59 and 60) of the resistor network, will provoke an increase in voltage directly proportional to the voltage increase controlled by the action of the microprocessor on network R/2R (53). The action of the microprocessor (52) can be utilized as an automatic sensitivity control, or for acting on detection sensitivity for signals associated with the color cyan or red, regardless of the quadrant, semi-axis, view or channel, thereby becoming a powerful apparatus for improving sorting accuracy. Finally, the detector (64) linked to level S1 will have logic state "0" at its output (63) when the signal potential (62) applied to its inverter input is less than the potential defined by level S1 at its non-inverter input (61); when the potential of the input signal (62) is greater than that of S1 at its output (63) it will have logic state "1".

Figure 6 shows a pair of electrical signals for cyan-red (33 and 34) and their digital values at the moment the signals reach their peak value. Also shown is the matrix panel (47) with a specific sorting matrix that contains data on unacceptable colors only in the first quadrant "Q1" and on the negative semi-axis "Y" (G-), as well as a rectangular stacked shape (65) showing the organization of addresses and the contents of the work memory that stores the sorting matrix on the panel. Because it is positive, the signal pair G-R defines a point in the first quadrant "Q1", which means that the address to be searched for in memory is found in the block identified in the drawing by "Q1", which corresponds to bytes 00 to 07 (hexadecimal code). Signal G (33), at its peak, reaches six detection levels and corresponds to the sixth vertical line of the block (65), in other words, hexadecimal address 05, since the address of the first line is 00. In view of this, once the contents of line 07 (66) have been read, we have data 11111000 (68), which corresponds to the sixth line (70) of the first quadrant on the matrix panel (47) displaying the control sorting matrix. The result of digitizing signals G-R, applying the matrix sorting process, is obtained through logic operation "E", bit by bit, between the digital signal R (36) and the contents of the address (68) defined by G and "Q1". This gives the result 00001000 (69), not zero, therefore showing that the signal pair G-R defines a point on the sorting matrix whose content is "1" and therefore pertains to the geometric place for points that characterize the color of unacceptable objects. Through various electronic circuitry, the results (69) of logic operation "E" affects the operation of the ejector valve on the sorting apparatus that physically separates acceptable and unacceptable objects. As a second example, signal R (71) is zero and signal G (72) is -1 volt, thereby defining a point on the negative (G-) semi-axis "Y". Once the address and memory contents have been identified, all based on the sorting matrix process, two digital numbers are then obtained (73 and 74). When they are submitted bit by bit to logic "E", a result equal to "0" is obtained, thus not activating the ejector valve because this characterizes an acceptable color for the object being analyzed.

Figure 7 represents one of the shapes of the matrix panel for use with eight-bit microprocessors, wherein each small circle inside can represent an LED and the center symbol (*) indicates the origin of the cartesian plane. Operational command keys for the matrix panel are shown in Fig. 10.

Figure 8 represents the matrix panel containing a sorting matrix in which "1", indicating an illuminated point, identifies the geometrical place for points with content "1" and distinguishes unacceptable colors. By the same token, "0" indicates a nonilluminated point and identifies the geometric place of points with content "0", or acceptable colors.

Figure 9 shows the matrix panel (47), a lit LED (79), a light-conductor cable (80), a photodetector (81) coupled to the light-conductor cable, a data input port (76), two LED buffer-drivers -- one (77) for acting on LEDs found on lines and the other (78) for acting on LEDs found in columns -- the microprocessor (42) that forms part of the general CPU, RAM (45) and ROM (46). Also shown are waveshapes relative to the activation of the LED and its change in logic state through the action of the light-conductor cable and its related circuit. Before explaining how the change in LED logic state is processed by the action of the light-conductor cable, it should be pointed out that LEDs are submitted to scanning, going from one LED to another on each line, through every line in the quadrant, following the sequence Q1-Q2-Q3-Q4 and then semi-axes R+, G+, R- and G-. Scanning is fast enough to prevent scintillation. The LED is represented by a small circle, with the black one corresponding to a lit LED and the black one to an unlit LED, based on the on-off indication (81). The waveshape (82) for the lit LED and the waveshape (83) for the unlit one are shown beside their corresponding circles. For operation of the circuit that allows for changing the LED logic state, one should first put the matrix panel in editing mode, then place the free point of the light-conductor cable (80) on the LED one wishes to activate (79). In editing mode, scanning speed is substantially reduced to the point where the scanning is visible. The other end of the light-conductor cable (80) is emplaced over a photodetector. While LEDs are being scanned, the microprocessor sends a command pulse (88) that causes the LED to turn on and immediately go off. The lit or unlit LED, although not corresponding to the LED toward which the light conductor is pointed, shows differing waveshapes (84 and 85). However, the light detector (81) shows no change in state, and when the microprocessor verifies this condition at the "door" (76), it verifies the change in state. At the moment LED scanning reaches the LED toward which the light conductor is pointed, the state changes (86, 87 and 88), which will be verified by the microprocessor. This process serves for creating, editing or modifying sorting matrixes.

Figure 10 is similar to Fig. 5A; therefore, the process for multiplexing and digitizing electrical signals for cyan (35) and red (36), along with the identification of quadrants and semi-axes (37), will not be discussed here. The channel microprocessor (41) is interlinked to the RAM (43) that contains the control sorting matrix and specific channel data (sensitivity, reference gain, etc.) as well as being interlinked to the ROM (44) that contains the channel control program and all its routines and subroutines. It is further interlinked to the general CPU microprocessor (42), the control system (49), the ejector valve (50), the multiplexer (30), and finally, to the digitized signal collector group, consisting of the latch-buffer (38, 39 and 40). The channel microprocessor (41), controlled by the channel operation program that is stored in ROM (44), utilizes interconnections (89 and 90) to retrieve data on digitized signals (35, 36 and 37), By necessity this data is relative to the same moment and has been temporarily retained in the latch-buffer collector circuitry (38, 39 and 40). It immediately processes this information, beginning with data relative to the quadrant-axis, continuing with data relative to cyan and red, after which it knows the address and contents of the memory to be consulted. As a final step in carrying out the sorting matrix process, it compares data relative to the pair G-R with the contents of the matrix address, as explained in the description for Fig. 6, in order to decide whether the bichromatically analyzed object should be rejected. The connections between the channel microprocessor (41) and the general CPU microprocessor are intended to transfer data relative to the sorting matrix, sensitivity control, gain control and channel-functioning supervision, all in accordance with the general operational program stored in the general CPU ROM (46). ROM (46) also contains sorting matrixes preprogrammed and recommended by the manufacturer ready for use by the operator. RAM (45) contains all sorting matrixes that have been created, modified or edited, as well as the matrix that has been sent to the matrix panel by the general microprocessor. Another function of the general microprocessor is to interpret all commands originating from the control panel (49) and transfer this data.

In conclusion, this invention refers to a color sorting apparatus, which includes a means of conveying objects, uniformly and individually, to the interior of an illuminated analysis chamber linked to electronic photodectors and circuitry with the ability to transform into electrical signals the light reflected, transmitted or emitted by the objects. It also includes apparatuses for dividing the objects into wanted and unwanted groups by means of a matrix sorting process in which color analysis of the objects utilizes a comparison between the electrical signals and the contents of the sorting matrix. This matrix can be selected, modified or created by the operator by means of a matrix selection apparatus. Otherwise, it can be generated by the automatic matrix apparatus by sampling the electrical signals resulting from passing a group of objects with specific color characteristics through the analysis chamber. The matrix generated by this process can also be modified by the operator by means of a matrix apparatus in order to maximize the performance of the invention.

Claims

1. Apparatus for sorting objects by color, equipped with means of conveying objects uniformly and individually to the interior of an illuminated analysis chamber connected to photodetectors, in which:
photodetectors are interconnected to electronic circuitry capable of transforming light reflected, transmitted or emitted by said objects into digitized electrical signals;
a matrix process is utilized for sorting objects by color through comparison of said digitized electrical signals to the contents of a sorting matrix;
there is a matrix apparatus that allows the operator to automatically select, modify or create said sorting matrix based on a sampling of electrical signals produced by passing a group of objects with specific color characteristics through said analysis chamber.

2. The apparatus of Claim 1, in which analog electrical signals captured by said photodetectors are digitized, in a nonbinary manner, by detectors on linearly staggered levels, said staggering being adjustable and, based on a detection reference level, containing a number of positive and negative levels equal to the number of bits comprising the digitized signal.

3. The apparatus of Claims 1 and 2, in which a matrix sorting process is adopted for the bichromatic sorting of objects, said process involving a cartesian plane containing said sorting matrix formed by points that define said geometric place for acceptable and unacceptable colors, with the color identification of said unacceptable objects taking place when the two digitized bichromatic signals considered as coordinates in said cartesian plane define points within said geometrical place for unacceptable colors in said sorting matrix.

4. The apparatus of Claim 3, in which for bichromatic selection said matrix process is limited to a matrix of points in the shape of a cartesian plane whose coordinates are linked to the two colors of the bichromatic analysis process, said matrix of points being that which contains said sorting matrix defining said geometric places for said acceptable and unacceptable colors.

5. The apparatus of Claim 4, in which, considering said matrix of points as an X-Y plane, the axis origin is taken as a reference for colors, the X axis is linked to one of the bichromatic signals and the Y axis to the other, with the number of points for each semi-axis being equal to the number of bits into which said bichromatic electrical signals have been digitized. The result is that each pair of digitized bichromatic signals obtained from a bichromatic lens and its two associated photodetectors can locate a point in said plane that contains said sorting matrix, thereby identifying the article color that has produced said bichromatic signals and thus classify the object as belonging to an acceptable or unacceptable group of objects.

6. The apparatus of Claim 5, in which there is a matrix panel that allows for the visualization of said sorting matrix, with said matrix panel in the shape of a cartesian plane comprising:
as many points as are necessary to display any sorting matrix, and
optical-electronic elements, preferably light-emitting diodes (LEDs), said elements representing points on said plane and defining bichromatic colors, and with each light-emitting element representing one point with content "1" and each non-light-emitting element representing one point with content "0", thus permitting a definition of said geometric place for points with content "1" and for those with content "0".

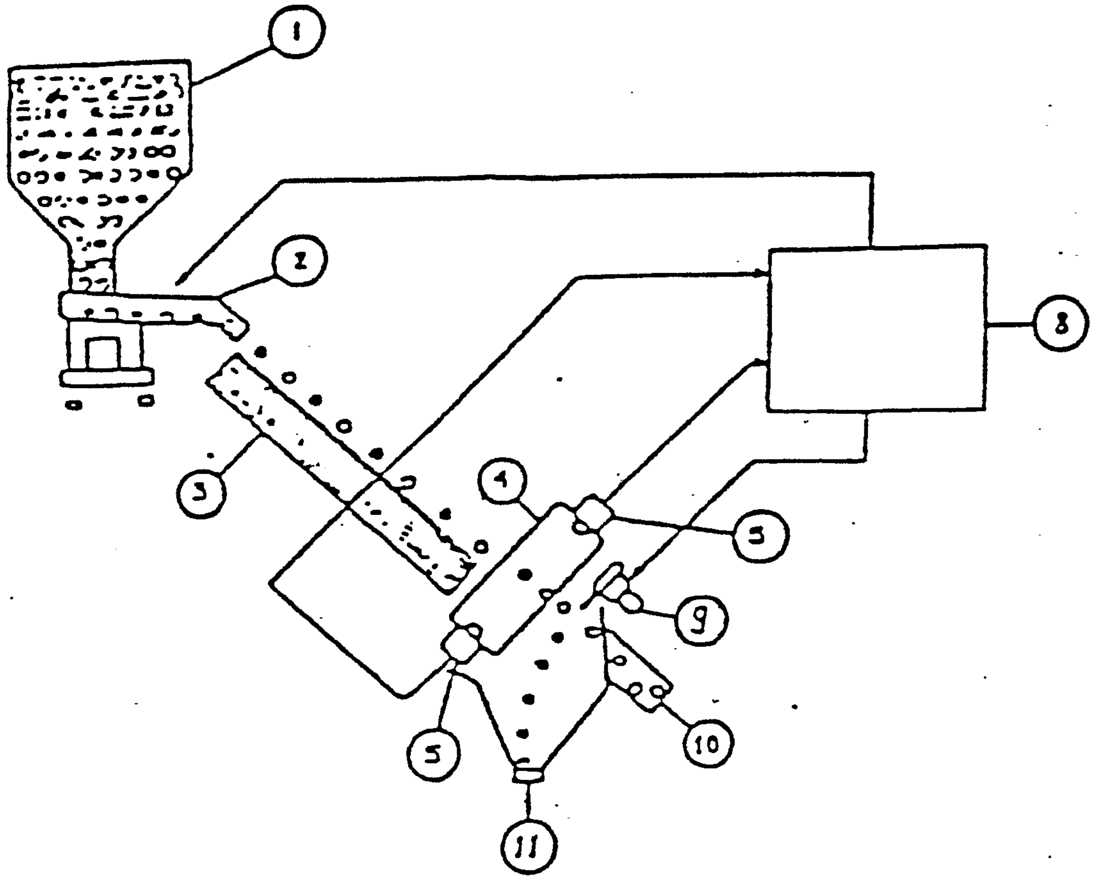
7. The apparatus of Claims 4, 5 and 6, in which there is a light-conducting cable, preferably an optical-fiber cable, connected to a photodetector on said matrix apparatus capable of detecting whether the luminous element on said matrix panel is or is not emitting light and of reversing the original condition of said element, thereby allowing the operator of said sorting apparatus to create, edit or modify a sorting matrix whose contents are on said matrix panel.

8. The apparatus of Claims 4, 5, 6 and 7, in which there is storage of sorting matrixes in RAM, ROM, EPROM or any other type of digital memory suitable for said application and that contains a matrix apparatus capable of identifying and selecting any one of said memories as the operational sorting matrix, reading its contents and displaying them on said matrix panel, as well as containing a means of copying, modifying and editing said sorting matrixes through said matrix panel and recording them in RAM for subsequent use.

9. The apparatus of the above Claims, in which there is an apparatus capable of automatically generating said sorting matrix based on a sampling of electrical signals produced by passing a group of objects with specific color characteristics through an analysis chamber, preferably a group of objects considered to be acceptable, with said sorting matrix generated by said automatic process being recorded in RAM and which may be read, modified and edited by said matrix apparatus.

10. The apparatus of the above Claims, in which each sorting channel may, in its analysis chamber, contain one or more optical groups connected to photodetectors that convert light into electrical signals that are digitized and transmitted to a process controller in real time, using microprocessors that analyze the color of each object in each channel, adopting said matrix sorting process to distinguish between acceptable and unacceptable objects by comparing said electrical signals to said sorting matrix.

Fig. 1



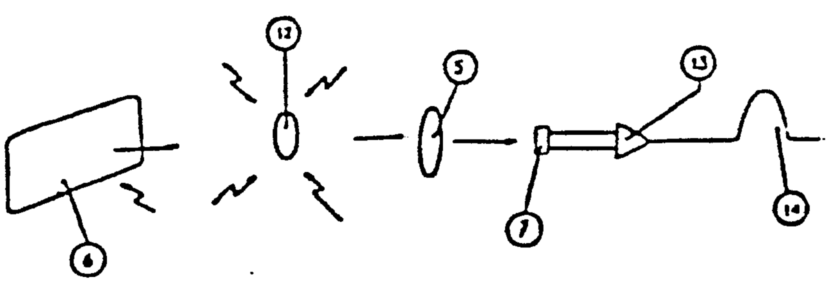


Fig. 2

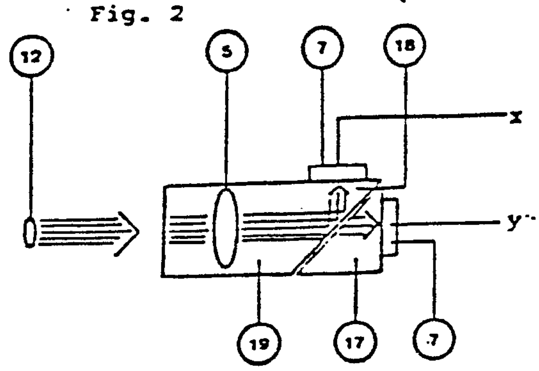
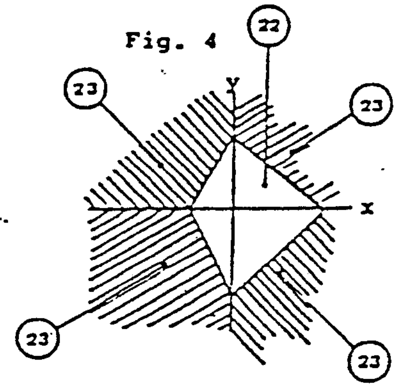


Fig. 4



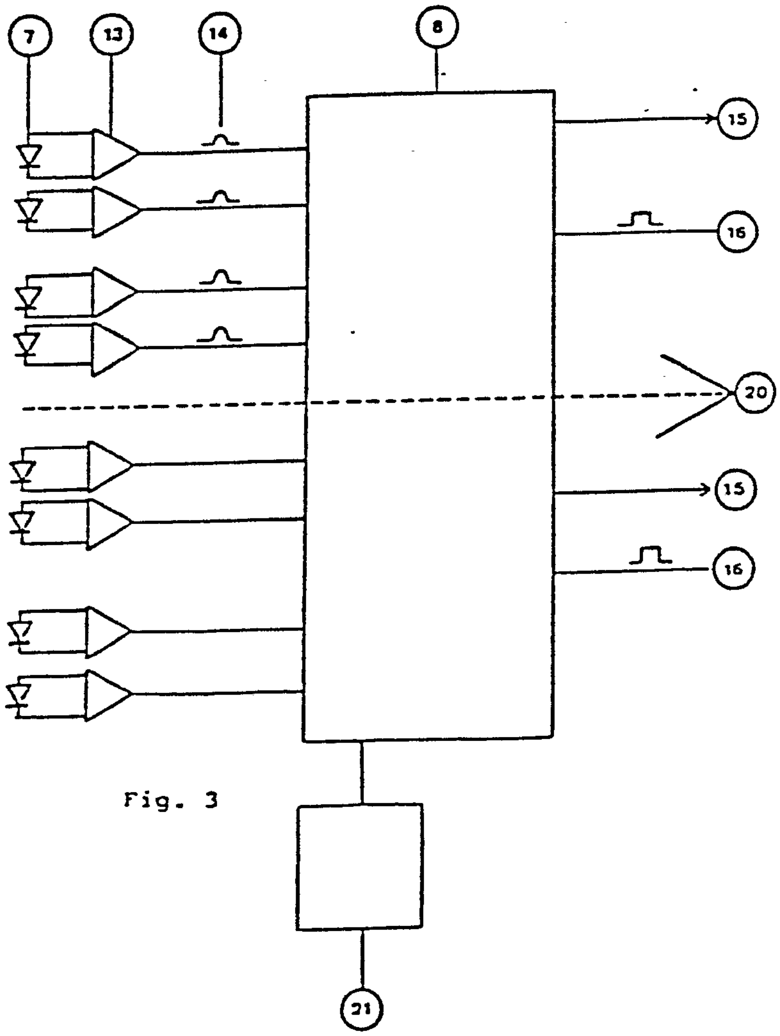


Fig. 3

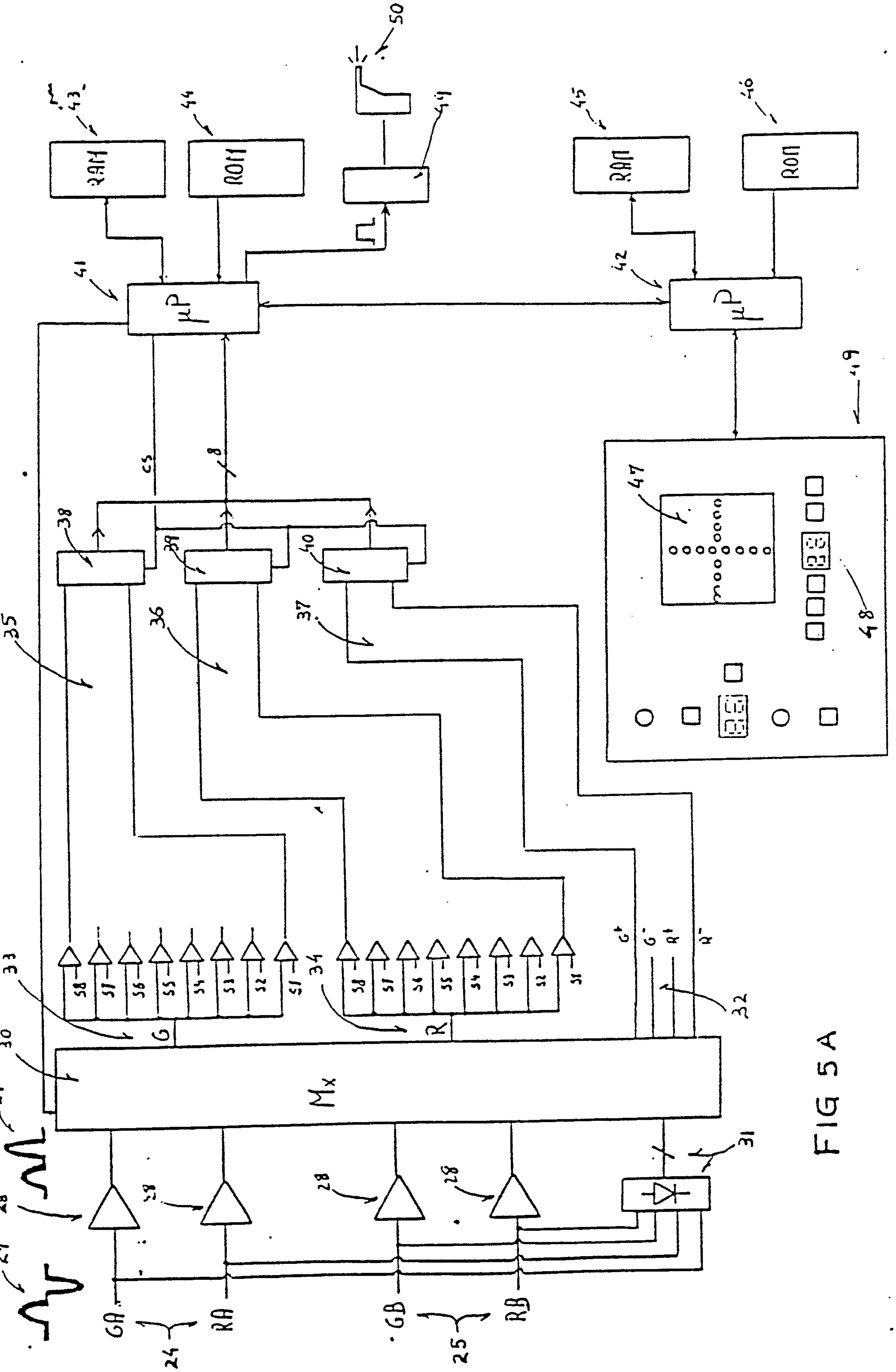
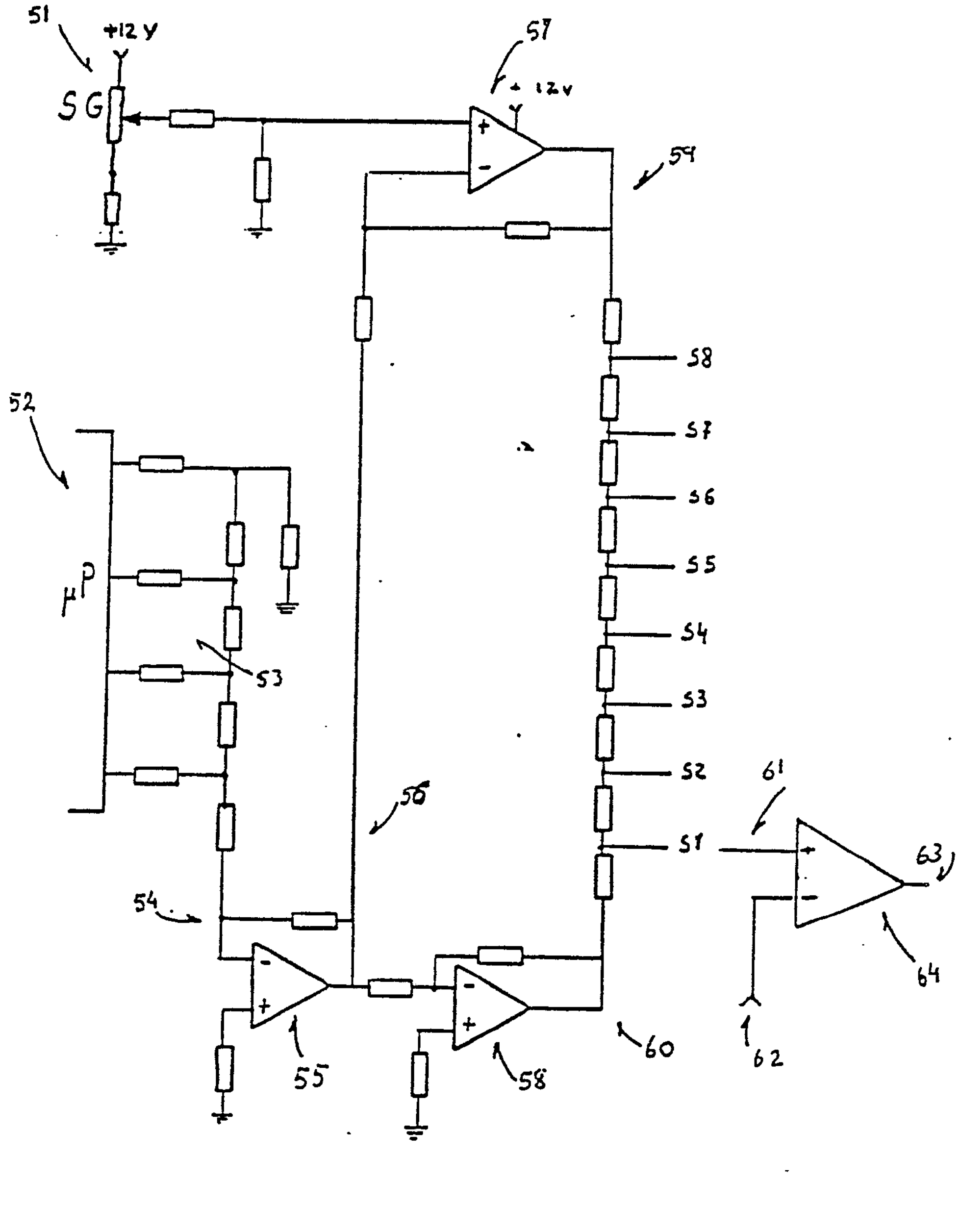


FIG 5A

FIG. 5B


51
+12 V
SG
57
+12V
59
52
μP
53
56
54
55
58
60
S8
S7
S6
S5
S4
S3
S2
S1
61
62
63
64

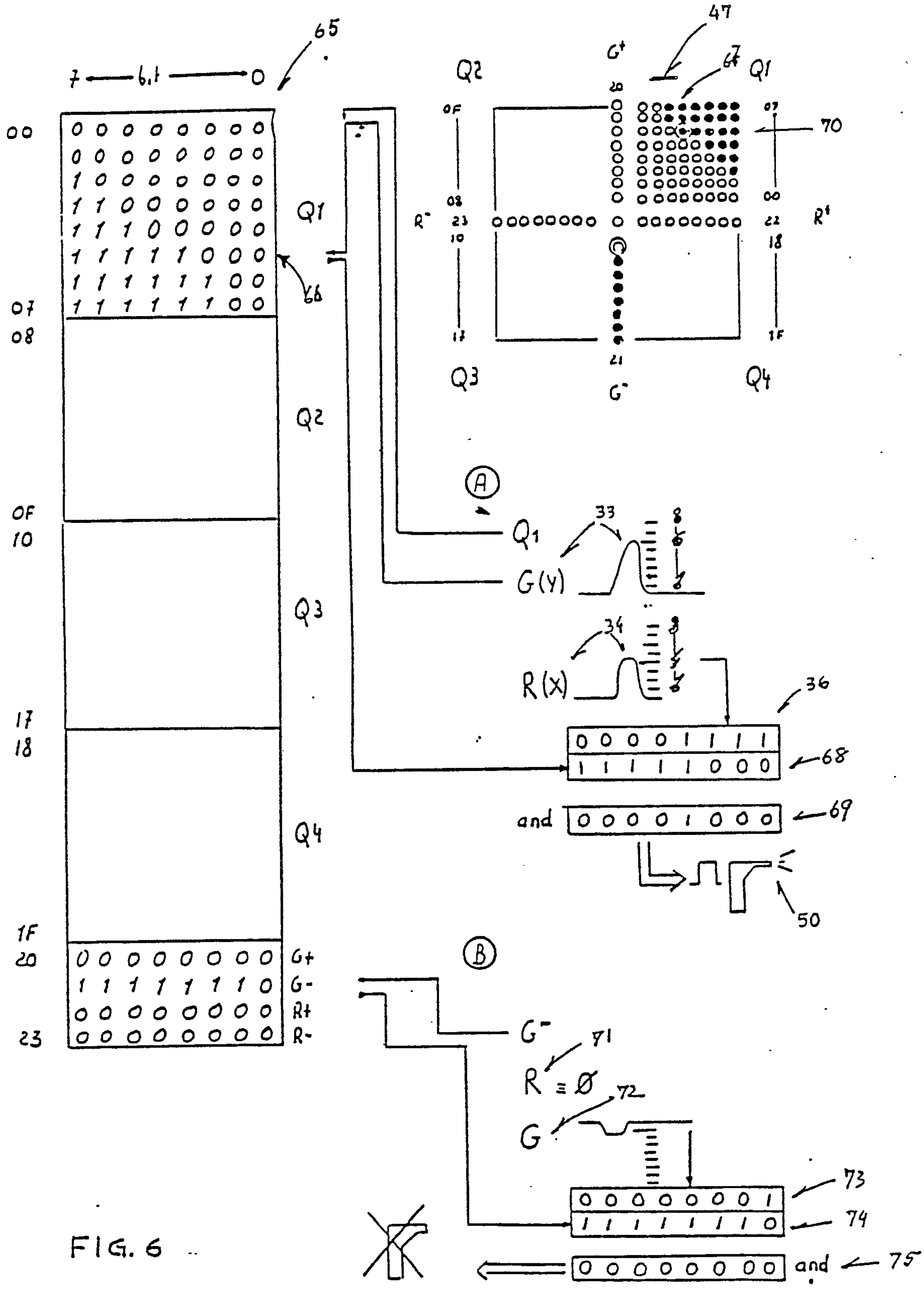


FIG. 6

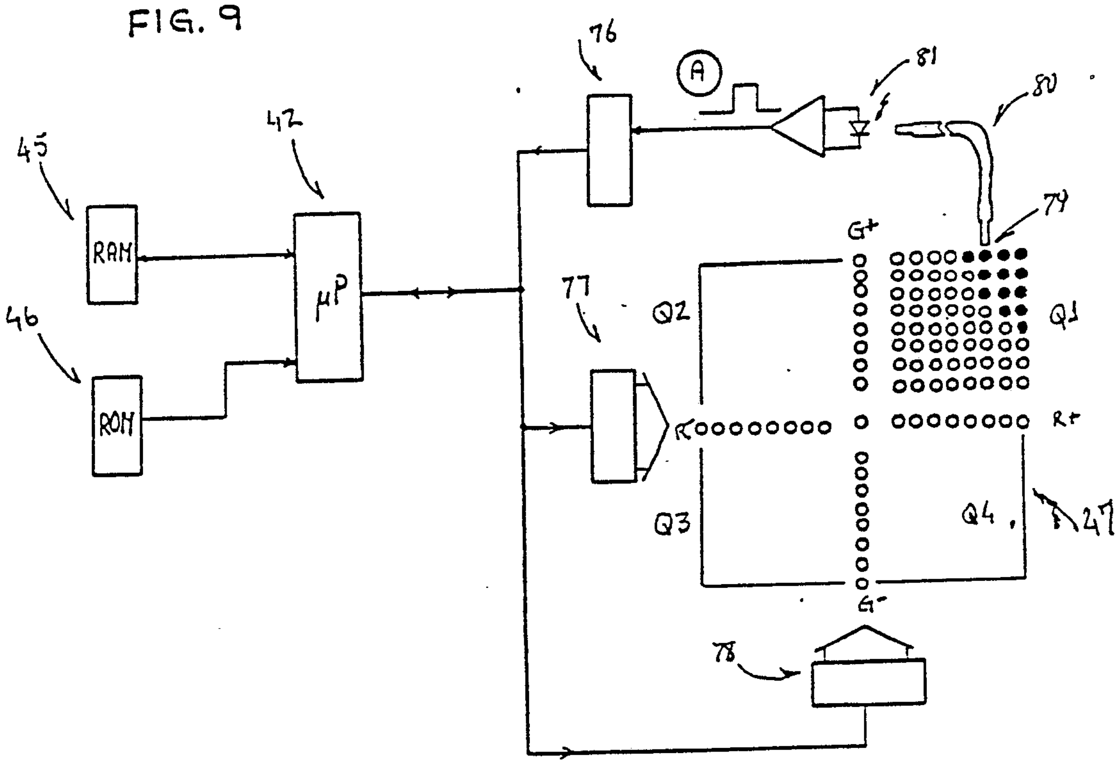
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	*	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FIG. 7

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1
1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1
1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1
1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	0	0	*	0	0	0	0	0	1	1	1
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

FIG 8

FIG. 9


76
A
81
80
45
42
RAM
μP
74
G+
46
77
Q2
Q1
ROM
R-
R+
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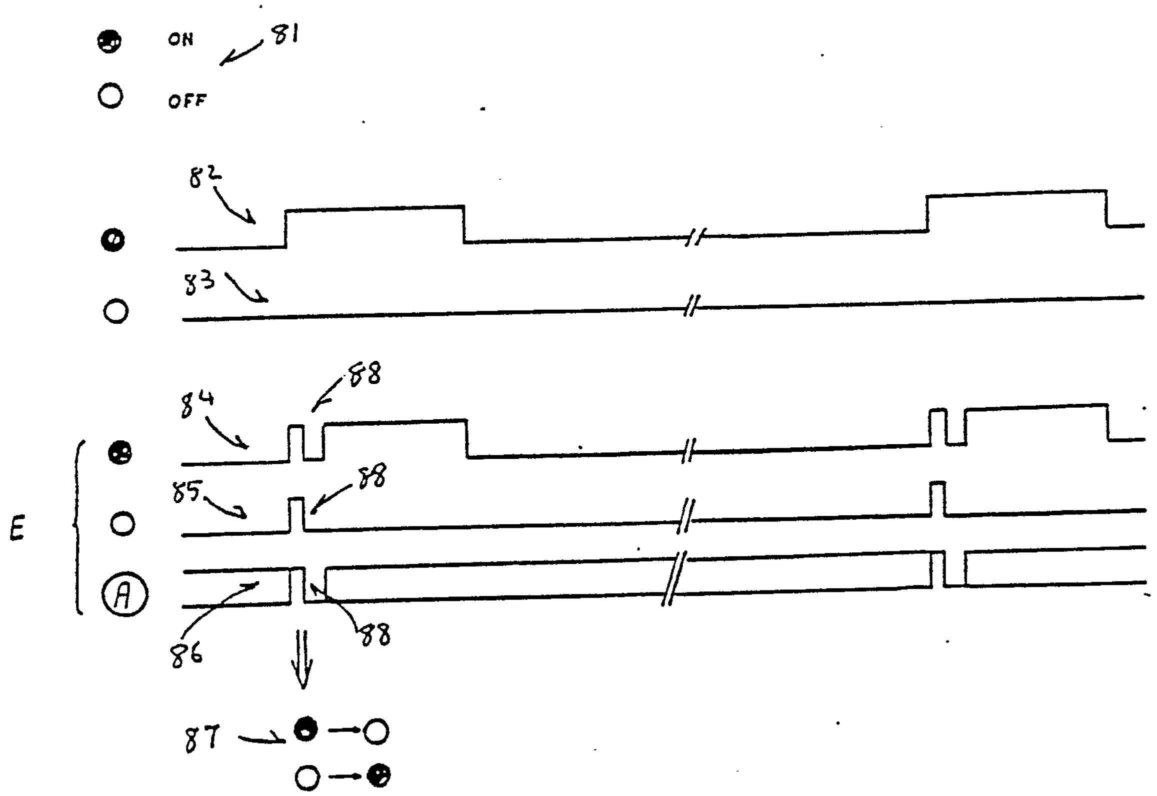
Q4
47
G-
78


ON
81
OFF
82
83
84
88
85
88
E
A
86
88
87

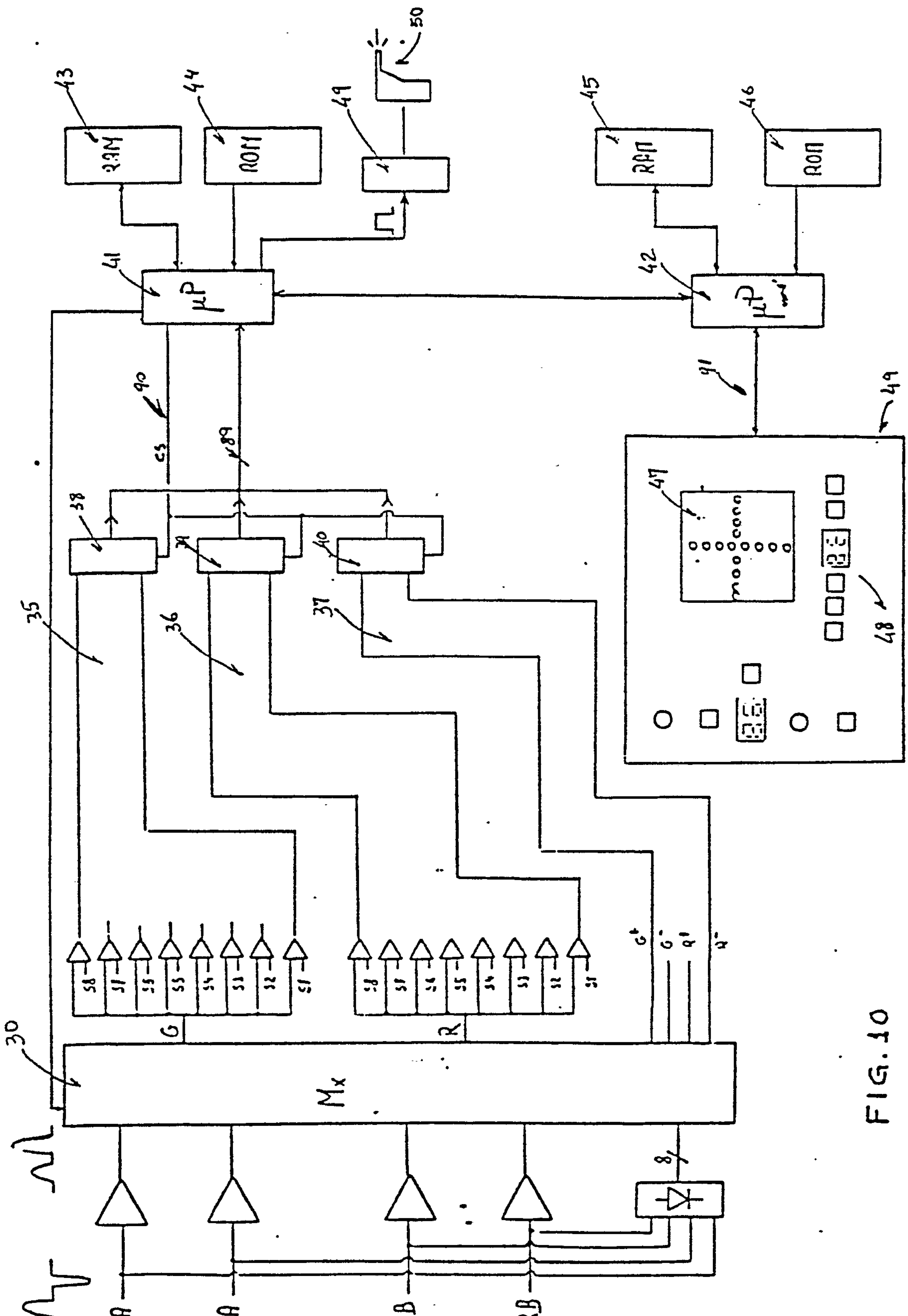


FIG. 10