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(71) Applicant: **TOYO INK MANUFACTURING CO., LTD.**
Tokyo (JP)

(72) Inventors:
- **Castegnier, Adrien**
  Quebec H2V 2Z2 (CA)
- **Castegnier, Guy**
  Quebec H3E 1L1 (CA)
- **Castegnier, Pierre**
  Quebec H3L 3A7 (CA)
- **Goyette, Charles**
  Quebec H2J 1T3 (CA)

(74) Representative: **Koepe, Gerd L., Dipl.-Chem.**
Koepe & Partner,
Patentanwälte,
Postfach 22 12 64
80502 München (DE)

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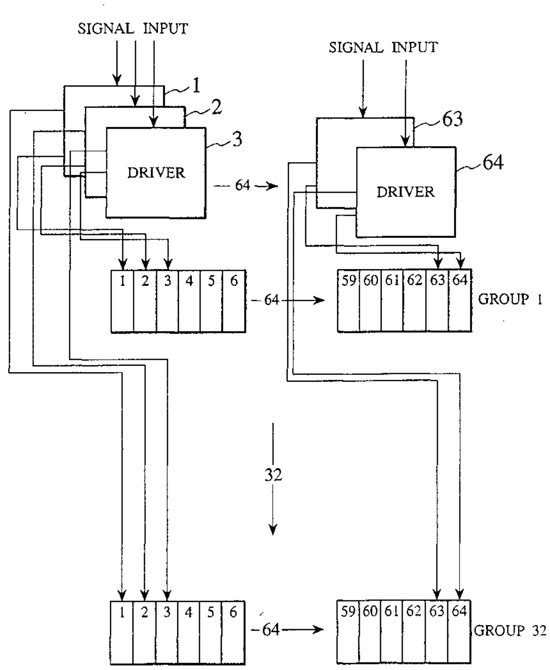
(54) Printing head system and graphic data transferring method

(57) A plurality of driver modules for energizing selected electrodes are mounted on a printing head. The printing head has 64 driver modules, each driver module connected to corresponding electrodes included in respective groups. Specifically, driver module No.1 is connected to electrode No.1 in group 1, electrode No.1 in group 2, ..., and electrode No.1 in group 32. Driver module No.2 is connected to electrode No.2 in group 1, electrode No.2 in group 2, ..., and electrode No.2 in group 32. During operation, at a time tl, each driver module sends a signal to a conductor connected to an associated electrode therewith in group 1. Then, at times t2, t3, ..., each driver module operates as above with respect to groups 2, 3, ..., sequentially. Meanwhile, when the pixel density values in a single group are partially different each other, a correction is performed.

FIG. 3



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a printing head system for use in an electrocoagulation printing apparatus, and more particularly relates a printing head system including a printing head supporting a linear array of electrolytically inert electrodes electrically insulated from one another. The linear array is divided into a plurality of groups, each having a predetermined number of electrodes which separate at a short distance one other.

[0002] The present invention also relates to a method for transferring graphic data to an electrocoagulation printing ink including an electrolytically coagulable polymer.

2. Prior Arts

[0003] In US Patent No.4,895,629 of January 23, 1990, Applicant has described a high-speed electrocoagulation printing method and apparatus in which use is made of a positive electrode in the form of a revolving cylinder having a passivated surface onto which dots of colored, coagulated ink representative of an image are produced. These dots of colored, coagulated ink are thereafter contacted with a substrate such as paper to cause transfer of the colored, coagulated ink onto the substrate and thereby imprint the substrate with the image. As explained in this patent, the surface of the positive electrode is coated with a dispersion containing an olefinic substance and a metal oxide prior to electrical energization of the negative electrodes in order to weaken the adherence of the dots of coagulated ink to the positive electrode and also to prevent an uncontrolled corrosion of the positive electrode. In addition, gas generated as a result of electrolysis upon energizing the negative electrodes is consumed by reaction with the olefinic substance so that there is no gas accumulation between the negative and positive electrodes.

[0004] The electrocoagulation printing ink which is injected into the gap defined between the positive and negative electrodes consists essentially of a polymer dispersion containing an electrolytically coagulable polymer, a dispersing medium, a soluble electrolyte and a coloring agent. Where the coloring agent used is a pigment, a dispersing agent is added for uniformly dispersing the pigment into the ink. After coagulation of the ink, any remaining non-coagulated ink is removed from the surface of the positive electrode, for example, by scraping the surface with a soft rubber squeegee, so as to fully uncover the colored, coagulated ink which is thereafter transferred onto the substrate. The surface of the positive electrode is then cleaned to remove therefrom any remaining coagulated ink.

[0005] The optical density of the dots of colored, coagulated ink, hereinafter referred to as "pixels", may be varied by varying the voltage and/or pulse duration of the pulse-modulated signals applied to the negative electrodes. As a typical example, the printing head which carries the negative electrodes may comprise 2048 electrodes which are arranged to define 64 groups or channels each having 32 electrodes. By proper electronic circuitry, it is possible to sequentially scan the electrodes of each channel while performing such a scanning simultaneously for all channels, and to apply a pulse-modulated signal to selected ones of the electrodes during scanning to energize same. The pulse-modulated signal may have a pulse duration ranging from about 15 to about 4000 nanoseconds. An electrical signal with a pulse duration of 150 nanoseconds provides a pixel having an optical density of 0.02 (very light gray), whereas an electrical signal with a pulse duration of 4000 nanoseconds provides a pixel having an optical density of 1.50 (black). It is also possible to vary the pulse duration by a predetermined number of time increments, for example, 63 increments of about 60 nanoseconds each or 255 increments of about 15 nanoseconds each, depending upon the level of fidelity of reproduction required. A signal whose pulse duration can be varied from 15 to 4000 nanoseconds in 255 increments delivers of course the best tone reproduction. Thus, in this case, the printing of a pixel starts with a pulse duration of about 15 nanoseconds up to 4000 nanoseconds and stops when the desired optical density is reached.

[0006] The negative electrodes are arranged in rectilinear alignment to define a series of corresponding negative electrode active surfaces which are disposed in a plane parallel to the rotation axis of the positive electrode and spaced from the surface thereof by a constant predetermined gap filled with the aforesaid electrocoagulation printing ink. Electrical energization of selected ones of the negative electrodes causes point-by-point selective coagulation and adherence of the ink onto the olefin and metal-oxide coated positive electrode surface opposite the electrode active surfaces of the energized negative electrodes while the positive electrode is rotating, thereby forming the aforesaid dots of colored, coagulated ink or pixels. The addressing mode of the negative electrodes is such that at any given time, a signal is impressed at a single electrode in each and every channel. In the example given above, at the beginning of the electrocoagulation printing, current injection is performed simultaneously through the 1st electrode of every channel; thus, 32 non-contiguous electrodes are energized at the same time. At the next cycle, the 2nd electrode in every channel is energized. This procedure is repeated until all the electrodes of the linear array have been energized.

[0007] Since the negative electrodes energized at any given point in time are non-contiguous and the film of electrocoagulation printing ink on the surface of the positive electrode constantly moves relative to the linear array of negative electrodes due to the rotation of the positive electrode, the electrode addressing mode creates a saw-toothed image resulting from the displacement of two adjacent pixels relative to one another along the direction of rotation of the positive electrode. Such a displacement is function of the time frame between the electrical energization of consecutive electrodes and also function of the speed of rotation of the positive electrode. The quality of the image thus reproduced is obviously less than perfect. Applicant has also observed the occurrence of overly dense pixels.

[0008] With reference to a drawing, the above described conventional art is explained again hereinunder.

[0009] Fig.1 illustrates the configuration of the negative electrodes in a prior art printing head. The printing head comprises a linear array of 2048 electrodes that are arranged into 64 groups each having 32 electrodes. The electrodes of the array are disposed along an imaginary line which extends generally transversely to the direction of movement of the film of electrocoagulation printing ink carried by the positive electrode. A driver circuit (not shown) electrically energizes selected ones of the negative electrodes to cause point-by-point selective coagulation of the polymer present in the ink, opposite the surfaces of the energized electrodes. The level of coagulation of the ink depends on the voltage and pulse duration of the pulse-modulated signals applied to the negative electrodes. For practical reasons, the voltage is held constant and only the pulse duration is varied to control the level of coagulation. In turn, the level of coagulation determines the optical density of each pixel in the image which is ultimately transferred onto the substrate.

[0010] The electrode addressing scheme of the prior art printing head is such that at time t1 the 1st electrode of each and every group is energized. The next current injection event occurring at t2 renders only the second electrode of each and every group active. This sequence is continued until every electrode of the array has been activated. In the example given above, a complete activation cycle requires 32 current injection events, one event rendering 64 electrodes active.

[0011] During each current injection event, the electrodes that are being activated are non-contiguous. In the arrangement shown at Fig.1, the distance between two active electrodes corresponds to the width of 31 electrodes. In other words, 31 inactive electrodes separate the active electrodes. Such an electrode addressing scheme creates the pixel distribution profile shown at Fig.2. This profile is characterized by a displacement of adjacent pixels relative to one another that results from the movement of the film of the electrocoagulation printing ink between successive current injection events. In Fig.2, this displacement is designated by reference numeral 10. The displacement is primarily function of the time between successive current injection events and the speed at which the film of electrocoagulation printing ink moves. The displacement may be important since electrocoagulation printing systems are designed to operate at high speed. For example, for a printing speed of one meter per second, the inter-pixel shift (or localized coagulation site) is of 4 micrometers when the current injection events occur at 4 microseconds intervals.

[0012] The inter-pixel shift depicted at Fig.2 is undesirable since it is easily perceived by the human eye and it adversely affects the quality of the image as it creates a saw-toothed image.

SUMMARY OF THE INVENTION

[0013] It is therefore an object of the invention to overcome the above drawbacks and to provide a printing head system for electrocoagulation printing, that is capable of improving the quality of the image reproduced by electrocoagulation of an electrolytically coagulable printing ink.

[0014] It is another object of the invention to provide a device for correcting the optical density of the pixels produced by electrocoagulation of an electrolytically coagulable printing ink, with a view to limiting the occurrence of overly dense pixels.

[0015] To achieve the above objects, according to an aspect of the present invention, there is provided, a printing head system for an electrocoagulation printing apparatus, said printing head system comprising: an electrode carrier; a linear array of electrolytically inert electrodes electrically insulated from one another and mounted to said electrode carrier, said array of electrodes being arranged into a plurality of groups each having a predetermined number of closely spaced electrodes; and a driver circuit for addressing the electrodes of selected groups, said driver circuit being responsive to a graphical data input signal to cause simultaneous passage of electric current through at least a major portion of the electrodes in a selected one of said groups, said major portion of electrodes including electrodes that are contiguous with one another.

[0016] According to a preferred embodiment of the present invention, said electrocoagulation printing apparatus includes a movable positive electrode carrying a film of electrocoagulation printing ink and adapted to displace said film along a predetermined direction, and wherein the electrodes of said array are arranged in rectilinear alignment along an imaginary line extending generally transverse to said predetermined direction.

[0017] According to a preferred embodiment of the present invention, the electrodes in a selected group define a generally rectilinear electrocoagulation zone extending generally transverse to said predetermined direction.

[0018] According to a preferred embodiment of the present invention, said driver circuit includes a plurality of driver modules each electrically coupled to a single electrode in every group of electrode.

[0019] According to a preferred embodiment of the present invention, said groups of electrodes each have the same number of electrodes.

[0020] According to a preferred embodiment of the present invention, the driver circuit is responsive to a first graphical data input signal for simultaneously initiating at a first point in time injection of electric current through a first group of electrodes, said driver circuit being further responsive to a second graphical data input signal for initiating at a second point in time simultaneous injection of electric current through a second group of electrodes, said first and second groups of electrodes being contiguous with one another, said second point in time occurring subsequently to said first point in time.

[0021] According to another aspect of the present invention, there is provided a method for transferring graphical data to an electrocoagulation printing ink containing an electrolytically coagulable polymer, said method comprising the steps of: a) providing a linear array of electrolytically inert electrodes electrically insulated from one another and in contact with a film of said ink moving along a predetermined direction, said array of electrodes being arranged into a plurality of groups each having a predetermined number of closely spaced electrodes; and b) addressing the electrodes of selected groups in response to a signal containing said graphical data, to cause simultaneous passage of electric current through at least a major portion of the electrodes in a selected one of the groups, said major portion of electrodes including electrodes that are contiguous with one another, thereby simultaneously inducing localized coagulation of said polymer at a plurality of contiguous sites arranged along an imaginary line extending generally transverse to said predetermined direction.

[0022] According to still another aspect of the present invention, there is provided, in an electrocoagulation printing apparatus including a printing head carrying a linear array of electrolytically inert electrodes electrically insulated from one another, said array of electrodes being arranged into a plurality of groups each having a predetermined number of closely spaced electrodes, the improvement comprising a signal processing device for correcting pixel density, said signal processing device including: an input for receiving a signal representative of a pixel density value associated with each electrode in one of said groups of electrodes; a signal processing circuit for altering a pixel density value associated with a selected electrode in said one group of electrodes at least partially in dependence of pixel density values associated with other electrodes in said one group; and an output coupled to the selected electrode for supplying thereto the altered pixel density value.

[0023] According to a preferred embodiment of the present invention, said processing circuit includes means for processing pixel density values associated with a plurality of electrodes in said one group and computing a correction factor for altering the pixel density value associated with said selected electrode.

[0024] According to yet still another aspect of the present invention, there is provided a pixel density correction device for processing a signal containing pixel density values conveyed to a printing head of an electrocoagulation printing apparatus that includes a plurality of simultaneously addressable electrodes, said pixel density correction device including: an input for receiving said signal representative of pixel density values associated with said simultaneously addressable electrodes; and a signal processing element for altering a pixel density value of a selected one of said simultaneously addressable electrodes, said signal processing element being responsive to pixel density values associated with electrodes other than said selected electrode to determine a corrected pixel density value associated with said selected electrode.

[0025] According to further aspect of the present invention, there is provided a method of correcting pixel density, comprising the steps of: a) processing a signal containing pixel density values conveyed to a printing head of an electrocoagulation printing apparatus that includes a plurality of simultaneously addressable electrodes to determine a corrected pixel density value associated with a selected one of said plurality of simultaneously addressable electrodes in dependence of pixel density values associated with electrodes other than said selected electrode; and b) outputting the corrected pixel density value.

[0026] According to still further aspect of the present invention, there is provided, in an electrocoagulation printing apparatus having a printing head with an array of electrodes and a driver circuit for impressing electric signals to individual electrodes of said array, the improvement wherein said driver circuit includes current limiting means for limiting the magnitude of electric current passing through individual electrodes to a predetermined value.

[0027] According to yet still further aspect of the present invention, there is provided a film of electrocoagulation printing ink containing a coagulated polymer with embedded graphical data, said film including a matrix of localized coagulation sites, said polymer being coagulated to a selected degree at each said site, said matrix comprising a row of contiguous sites that extend along an imaginary straight line.

[0028] The nature, principle and utility of the invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Further features and advantages of the invention will become more readily apparent from the following description of preferred embodiments, reference being made to the accompanying drawings, in which:

Fig.1 is a general schematic view illustrating the configuration of the electrodes array in a prior art printing head for use in an electrocoagulation printing apparatus;
Fig.2 illustrates the distribution of the locally coagulated sites in the electrocoagulation printing ink, that are created with the electrode configuration shown in Fig.1;
Fig.3 is a schematic view of the array of electrodes in a printing head according to a preferred embodiment of the invention;
Fig.4 is a diagram illustrating the pulse duration through the electrodes of a selected group designed to create in the electrocoagulation printing ink sites of different level of coagulation;
Fig.5 illustrates the distribution of the localized coagulation sites in the electrocoagulation printing ink obtained by using a printing head in accordance with the invention;
Fig.6 is an algorithm for correcting pixel density values;
Figs.7a to 7d show graphs of pixel density values associated with a group of electrodes to illustrate the possible correction levels that may be implemented in dependence of the pixel values distribution profile;
Fig.8 is a block diagram of an electronic device for effecting pixel density correction; and
Fig.9 is a schematic view illustrating a printing head provided with a driver circuit featuring a current limiting system, in accordance with a preferred embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] The detail description of the preferred embodiments will be made with reference to the accompanying drawings hereinunder.

[0031] Fig.3 illustrates schematically the connection between the electrodes and the driver circuit that controls the activation of the electrodes. Physically, the electrodes are disposed in the same manner as in the prior art printing head depicted in Fig.1. For ease of illustration, the various electrode groups have been shown at Fig.3 as being vertically offset; however, it should be understood that the electrode groups are arranged consecutively to form the linear array shown in Fig.1. A plurality of driver modules are mounted in the printing head for energizing selected ones of the electrodes. The printing head is provided with 64 driver modules, each module being connected to a respective electrode of every group. More specifically, module No. 1 is connected to electrode No. 1 of group 1, electrode No. 1 of group 2, etc. Driver module No. 2 is connected to electrode No. 2 of group 1, electrode No. 2 of group 2, etc.

[0032] In operation, at time t1 each driver module impresses a signal on the conductor leading to the associated electrode of the first group. Preferably, the voltage level of the signal is uniform across the electrodes of the group. In a most preferred embodiment, the voltage is about 40-60 volts. The pulse duration of the pulse-modulated signal, however, usually varies from one electrode to another. This enables to coagulate the polymer present in the electrocoagulation printing ink in contact with the electrodes of a selected group according to a pattern corresponding to the graphical data contained in the signal that is communicated to the printing head. Fig.4 best shows this feature. In this example, the electrocoagulation printing ink at the sites associated with electrode Nos. 1 to 30 will be coagulated the least since the pulse duration of the signal applied to this sub-group of electrodes is the shortest. A higher level of coagulation will be obtained at the sites associated with electrode Nos. 31 to 45. The level of coagulation at the sites associated with electrode Nos. 46 to 57 is at a level intermediate between the levels for electrode Nos. 1 to 30 and Nos. 31 to 45. Finally, the level of coagulation is highest at the sites associated with electrode Nos. 58 to 64 where the pulse duration is the longest.

[0033] A highly coagulated electrocoagulation printing ink will produce a dark pixel when the coagulated ink is transferred onto a suitable substrate, such as paper. Thus, in the above example, the sub-group of electrode Nos. 1 to 30 will create 30 relatively light pixels. Electrode Nos. 58 to 64 will form dark pixels. The pixels formed by the remaining electrodes of the group will have optical density values between those of sub-group 1 to 30 and 58 to 64.

[0034] The pattern of pixels on the substrate is shown in Fig.5. Each group of electrodes creates a collection of 64 pixels that exhibit no shift or displacement along the direction of movement of the film of electrocoagulation printing ink relative to the printing head. This pixel pattern has been found to significantly improve the image quality since the saw-tooth effect is virtually eliminated. However, a shift occurs at the boundary between adjacent pixel collections formed by different electrode groups, such as for example, the collections formed at t1 and t2. Although being undesirable, such a shift has not been found particularly objectionable as it is very difficult to perceive visually.

[0035] Here, it is to be noted that it is not necessary to activate all the 64 electrodes in a group. It may be enough to activate a main part of the 64 electrodes.

[0036] The method consists of simultaneously energizing contiguous electrodes of the array, as described above, is capable of substantially eliminating the undesirable saw-tooth effect that occurs with prior art printing heads. In order to further improve the print quality, Applicant has discovered that by implementing a novel pixel density correction method, higher levels of precision in the optical densities of the pixels can be achieved. The term "pixel density" as used herein refers to the optical density of a pixel formed by electrocoagulation of the polymer present in an electrocoagulation printing ink. Without being bound by a certain theory, it is believed that a certain pixel density or shade unbalance can occur when contiguous electrodes of the array are simultaneously energized. This unbalance is believed to result from a certain impedance variation in the electrocoagulation printing ink, producing higher currents than those normally expected. Accordingly, the pixel density is higher particularly at light shaded areas. As discussed earlier, varying the duration of the current injection event controls the pixel density. Each driver module impresses at the respective electrode a constant voltage signal and the duration of that signal determines the level of pixel density. This mode of operation, however, is based on the assumption that the magnitude of the current through the film of electrocoagulation printing ink is constant. In most instances, this assumption is true. However, when a number of contiguous electrodes are energized simultaneously, the impedance may no longer remain constant and this creates for some of the electrodes higher currents than those normally expected.

[0037] One possibility to correct this potential difficulty is to alter the signal applied to the individual driver modules to compensate for the impedance imbalance. In a most preferred embodiment, the pixel density value associated with every electrode is compensated, the level of compensation being dependent upon the pixel density value of at least one neighboring electrode. Preferably, the level of compensation for one electrode is established on the basis of the pixel density values which are associated with the neighboring electrodes and which are numerically higher (lighter shades) than the pixel density value associated with the electrode being currently compensated.

[0038] The method of correcting pixel density is illustrated in Fig.6. The flow chart depicts an operational loop that examines the pixel density value associated with each electrode of a given group from the array. At every loop, a pixel density correction value is calculated for the current electrode and stored in a table. When the pixel density value for the last electrode in the group has been processed, the correction is implemented and the resulting corrected signal is transferred to the respective driver modules of the printing head.

[0039] The graphical data input signal which is applied to the printing head is a digital signal containing a number of discrete pixel density values. Typically, each pixel density value is an 8-bit string that can take 256 different values. In other words, each electrode can be assigned a pixel density value from 0 to 255, where 0 is black while 255 is white, the intermediate values designating different gray levels. For convenience, the shade values are being described in this example with reference to black and white printing. If another color is applied, say red, 0 will refer to pure red, 255 to absence of red, while the intermediate values will refer to different shades of red. In the absence of any correction, the 8-bit strings are transferred to the respective driver modules which apply corresponding signals to the electrodes, whose duration is determined by the magnitudes of the 8-bit strings.

[0040] It has been found that an optimum area in the signal distribution path to effect the correction is at a point intermediate the source of the original digital signal and the driver modules. A pixel density correction system can be placed at any point location between these extremities to intercept the non-corrected digital signal, alter the signal in accordance with a predetermined algorithm and then transfer the corrected signal to the driver modules of the printing head. In a most preferred embodiment, the correction algorithm compares each pixel density value to the average pixel density values in the group denoting lower pixel densities (numerically higher values). If the given pixel density is far from the average, a strong correction will be required. Also, a strong correction will be made when there are many assigned lower pixel densities in the group. The correction is usually done by reducing the optical density of the pixel, in other words increasing the magnitude of the pixel density value. Fig.7 illustrates typical situations:

a) In Fig.7a, the density of the lower part of the electrode group is very far from average. Many pixels have a density lower than those of the lower part. Thus, a strong correction will be required.
b) In Fig.7b, the density of the lower part of the electrode group is near average. Many pixels have a density inferior to those of the lower part. The correction will be less than for group a.
c) In Fig.7c, the density of the lower part of the electrode group is very far from average. Few pixels have a density lower than those of the lower part. The correction will be less than for group a and similar to that of group b.
d) In Fig.7d, the density of the lower part of the group is near average. Few pixels have a density inferior to those of the lower part. The correction will be the lightest of all four groups.

[0041] Referring back to Fig.6, the first step of the correction algorithm is to analyze the digital signal in order to create a histogram of the pixel density values associated with a given electrode group. The objective is to classify the 64 random values in ascending order and associate with each discrete value the number of times it appears in the group, in other words, the number of electrodes that will be assigned this particular pixel density value(Step S401). An example of the histogram is shown in Table 1. In Table 1, the term "frequency" refers to the number of times each pixel density value appears in the group:

Table 1

Pixel density value	Frequency
000	0
001	2
002	0
003	1
004 to 252	etc
253	11
254	8
255	0

[0042] Once the histogram is built, the iteration process is initiated(Step S402 to Step S407). The first step is to locate in the table the maximum pixel density value associated with an electrode. In this example, 255 is not a valid entry since no electrode is assigned this value. The next value (i.e. 254), however, is valid. The next step is to calculate a correction factor for this entry. The following variables are utilized in the calculation:

a) total: in this case total = maximum pixel density value (associated with a non-zero frequency) × frequency (i. e. 254 × 8),
b) accumulated pixels = summation of the frequency value since the beginning of the iteration (in the first iteration, accumulated pixels = 8),
c) average = total / accumulated pixels (in the first iteration, the average is the same as total which in the example is 254).

[0043] The correction factor for the pixel density value 254 is obtained by means of the following equation: correction factor = ((average-current pixel value) × total)/ ✎ , where ✎ is a constant and the current pixel value for the first iteration is 254. Accordingly the correction factor at the first iteration is 0.

[0044] The constant ✎ is used to calibrate the results of the above equation by introducing therein a value that permits to fine tune the pixel density value compensation. The constant ✎ is obtained experimentally. More specifically, a constant ✎ that has been used with success during tests conducted by Applicant is obtained from an array of 256 values that describe a logarithmic curve. The array is reproduced as shown in Table 2 below. The value in brackets is an index allowing to retrieve from the array the value of the constant ✎ .

Table 2

ℓ[0]=100000	ℓ [1]=100000	ℓ [2]=99000	ℓ [3]=99000	ℓ [4]=99000
ℓ [5]=99000	ℓ [6]=99000	ℓ [7]=99000	ℓ [8]=98000	ℓ [9]=98000
ℓ [10]=98000	ℓ [11]=98000	ℓ [12]=98000	ℓ [13]=98000	ℓ [14]=97000
ℓ [15]=97000	ℓ [16]=97000	ℓ [17]=97000	ℓ [18]=97000	ℓ [19]=97000
ℓ [20]=96000	ℓ [21]=96000	ℓ [22]=96000	ℓ [23]=96000	ℓ [24]=96000
ℓ [25]=96000	ℓ [26]=95000	ℓ [27]=95000	ℓ [28]=95000	ℓ [29]=95000
ℓ [30]=95000	ℓ [31]=95000	ℓ [32]=94000	ℓ [33]=94000	ℓ [34]=94000
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ℓ [60]=90000	ℓ [61]=90000	ℓ [62]=90000	ℓ [63]=90000	ℓ [64]=90000
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ℓ[174]=66000	ℓ[175]=65000	ℓ[176]=65000	ℓ[177]=65000	ℓ[178]=64000
ℓ[179]=64000	ℓ[180]=63000	ℓ[181]=63000	ℓ[182]=62000	ℓ[183]=62000
ℓ[184]=61000	ℓ[185]=61000	ℓ[186]=60000	ℓ[187]=60000	ℓ[188]=59000
ℓ[189]=59000	ℓ[190]=58000	ℓ[191]=58000	ℓ[192]=57000	ℓ[193]=57000
ℓ[194]=56000	ℓ[195]=56000	ℓ[196]=55000	ℓ[197]=55000	ℓ[198]=54000
ℓ[199]=54000	ℓ[200]=53000	ℓ[201]=53000	ℓ[202]=52000	ℓ[203]=52000
ℓ[204]=51000	ℓ[205]=51000	ℓ[206]=50000	ℓ[207]=50000	ℓ[208]=49000
ℓ[209]=49000	ℓ[210]=48000	ℓ[211]=48000	ℓ[212]=47000	ℓ[213]=47000
ℓ[214]=46000	ℓ[215]=46000	ℓ[216]=45000	ℓ[217]=45000	ℓ[218]=44000
ℓ[219]=44000	ℓ[220]=43000	ℓ[221]=43000	ℓ[222]=42000	ℓ[223]=41000
ℓ[224]=41000	ℓ[225]=40000	ℓ[226]=40000	ℓ[227]=39000	ℓ[228]=39000
ℓ[229]=38000	ℓ[230]=38000	ℓ[231]=37000	ℓ[232]=37000	ℓ[233]=36000
ℓ[234]=36000	ℓ[235]=35000	ℓ[236]=34000	ℓ[237]=33000	ℓ[238]=32000
ℓ[239]=31000	ℓ[240]=30000	ℓ[241]=29000	ℓ[242]=28000	ℓ[243]=27000
ℓ[244]=26000	ℓ[245]=25000	ℓ[246]=24000	ℓ[247]=23000	ℓ[248]=22000
ℓ[249]=21000	ℓ[250]=20000	ℓ[251]=18000	ℓ[252]=16000	ℓ[253]=14000
ℓ[254]=12000	ℓ[255]=10000			

[0045] The specific value ℓ used depends upon the operational conditions of the printing apparatus. If these conditions are changed, a different ℓ value is used to fine-tune the correction factor. It is also possible to apply modifiers to the constant ℓ in order to compensate for changes that may occur during utilization of the printing apparatus. Two types of modifiers can be implemented:

1 - additive modifier (offset) Adds a constant value (offset) to each entry in the array of values for the constant ℓ. The offset can vary (for example) from - 9999 to + 50000. The neutral element is zero. The effect of this offset on the constant ℓ increases with the magnitude of the absolute value of the offset.

2 - multiplicative modifier (gain) Multiplies each entry in the array of values for the constant ℓ. The gain can vary (for example) from 0.2 to 5.0. The neutral element is 1. The effect of this gain on the constant ℓ increases as the magnitude of the gain value differs from the neutral element.

[0046] The modifiers can be used in the following fashion to alter the values in the array:

$$\angle[x] = (\text{offset} + \text{original } \angle[x]) \times \text{gain}$$

where $\angle$ [x] is the modified value stored at index **x** in the array (**x** having a value from 0 to 255), and original $\angle$ [x] is the original value at index **x** in the array.

[0047] The following Tables 3 and 4 describe the effect of the modifiers:

Table 3

OFFSET	Effect on low densities	Effect on high densities
Lower than 0: -999 < Offset < 0 Greater than 0: 0 < Offset < 5000	Correction greatly increased Correction greatly decreased	Correction slightly increased Correction slightly decreased

Table 4

GAIN	Effect on low densities	Effect on high densities
Lower than 1: 0.2 < Gain < 1.0	Correction moderately increased	Correction greatly increased
Greater than 1: 1.0 < Gain < 5.0	Correction moderately decreased	Correction greatly decreased

[0048] Once the appropriate value of the constant $\angle$ is selected from the array, the correction factor is calculated and stored.

[0049] The process continues by initiating another iteration for the next pixel density value in the table (i.e. 253). The first step is to update the total variable(Step S403). The updated variable total = total + (current pixel density value × frequency). For this iteration, the current pixel density value is 253 and the frequency 11. As a result, the value of the updated total variable is 4815. In general terms, the variable total can thus be mathematically expressed as the following formula (1).

$$\text{Total} = \sum_{i=a}^{\max} P_i N \qquad \text{......(1)}$$

where:

the range **a** to **max** is an index range in the table of pixel density values, the index **i** in that range pointing to pixel density values exceeding or equal to the pixel density value associated with a given electrode;
P_i is the pixel density value at the value taken by index **i**; in the example shown above the **i** and P_i are the same values; and
N is the number of electrodes assigned the pixel density value P_i taken by **i** at a given iteration from **a** to **max**.

[0050] In the next step of the process, the accumulated pixels variable is updated (Step S404). The updated variable accumulated pixels = accumulated pixels + frequency. Here, the updated accumulated pixels equals 8 + 11 = 19. In general terms, the accumulated pixels can thus be mathematically expressed as the following formula (2).

$$\text{Accumulated pixels} = \sum_{i=a}^{\max} N \qquad \text{......(2)}$$

[0051] The following step is to update the value of the variable average(Step S405). For this iteration, the updated value of average is 4815(updated total value)/19(updated accumulated pixels value) = 253.42. This is expressed by a general formula as the following formula (3).

$$\text{Average value} = \left(\sum_{i=a}^{\max} P_i N\right) \div \left(\sum_{i=a}^{\max} N\right) \qquad \text{......(3)}$$

[0052] The final step is to calculate the correction factor(Step S406). Using the above formula, the value of correction factor = ((253.42 - 253) X 4815) / ℓ is obtained and stored. The formula for obtaining the correction factor is expressed by a general formula as the following formula (4).

$$\text{Correction factor} = \left(\left(\left(\sum_{i=a}^{\max} P_i N\right) \div \left(\sum_{i=a}^{\max} N\right) - j\right)\left(\sum_{i=a}^{\max} P_i N\right)\right) \div \ell \qquad \text{......(4)}$$

[0053] The final step of the iteration is to determine if other pixel density values remain in the histogram. In other words, does the histogram contain other valid pixel density values less than the current value(Step S407). In the affirmative, a new loop is initiated, otherwise the calculated correction factor is applied(Step S408) and then the procedure terminated. If the procedure is indeed ended, the system then simply adds the correction factors to the original pixel density values. As a result, for example, the following Table 5 is obtained.

Table 5

Electrode number	Original pixel density value	Correction factor	Final pixel density value
1	117	9	126
2	254	0	254
3	253	0	253
4	212	2	214
5 to 61	......	.....	.....
62	198	3	201
63	198	3	201
64	220	1	221

[0054] Most preferably, the pixel density correction system is implemented by using the electronic device 100 illustrated in Fig.8. The device 100 comprises an input buffer 102 which receives the digital signal containing the pixel density values. A processor 104 operates on the data placed in the input buffer 102 in accordance with instructions stored in a memory 106. The corrected pixel density values are then transferred to an output buffer 108 that issues a modified digital signal directed to the printing head.

[0055] In a different embodiment, the printing head is provided with a driver circuit featuring a current limiting system for restricting the magnitude of electric current passing through the electrodes of the array at predetermined levels. This arrangement is capable of avoiding the occurrence of overly dense pixels on the substrate, caused by impedance variations in the electrocoagulation printing ink, without the necessity of implementing a pixel density value correction system of the type described above. The printing head arrangement is schematically depicted in Fig.9. For simplicity, only a single electrode group has been depicted. The system resides in the inclusion of a current source 200 associated with each electrode, that can be integrated in the respective driver module. Each current source feeds only a current of predetermined magnitude to the respective electrode, with the result that the impedance of the electrocoagulation printing ink no longer determines the current magnitude. Thus, impedance variations in the electrocoagulation printing ink are not likely to cause any current magnitude changes. As a result, all the electrodes coagulate ink locally at an expected level.

[0056] The current source can be of any appropriate design. Most preferably, the current source is selected to maintain the current constant during the current injection event. For example, use can be made of the adjustable voltage regulator sold under part No. LM117HV by National Semiconductor Corporation, having an output terminal and an adjustment terminal with a resistor connected therebetween. In operation, the LM117HV develops a nominal 1.2 V reference voltage between the output and adjustment terminals and, since the voltage is constant, a constant current flows through the resistor. Thus, by selecting a 12 Qresistor, a constant current of 100 mA is delivered to the electrodes. This current will remain constant even if there are variations in the electrical resistance of the film of electrocoagulation printing ink. Another possibility is to use a hybrid circuit that is designed to prevent the current from exceeding a predetermined value. In this embodiment, the impedance of the electrocoagulation printing ink determines the current magnitude, as long as this magnitude remains within a predetermined operational range. However, should the impedance drop, the current reaches the upper extremity of the range and it is forced to remain there to avoid over-coagulation of the ink.

[0057] It is to be noted, here, that when the driver circuit cause simultaneous passage of electric current through selected electrodes of the array that are contiguous with one another, the above current limiting system prevents that a magnitude of current passing through either one of the electrodes that contiguous exceeds a predetermined value.

[0058] It should be understood that many modifications and adaptations of the invention will become apparent to those skilled in the art and it is intended to encompass such obvious modifications and changes in the scope of the claims appended hereto.

Claims

1. An electrocoagulation printing apparatus including a printing head carrying a linear array of electrolytically inert electrodes electrically insulated from another, said array of electrodes being arranged into a plurality of groups each having a predetermined number of closely spaced electrodes, said apparatus comprising a signal processing device for correcting pixel density, said signal processing device including:

- an input for receiving a signal representative of a pixel density value associated with each electrode in one of said groups of electrodes;
- a signal processing circuit for altering a pixel density value associated with a selected electrode in said one group of electrodes at least partially in dependence of pixel density values associated with other electrodes in said one group; and
- an output coupled to the selected electrode for supplying thereto the altered pixel density value.

2. The apparatus defined in claim 1, wherein said processing circuit includes means for processing pixel density values associated with a plurality of electrodes in said one group and computing a correction factor for altering the pixel density value associated with said selected electrode.

3. A pixel density correction device for processing a signal containing pixel density values conveyed to a printing head of an electrocoagulation printing apparatus that includes a plurality of simultaneously addressable electrodes, said pixel density correction device including:

- an input for receiving said signal representative of pixel density values associated with said simultaneously addressable electrodes; and
- a signal processing element for altering a pixel density value of a selected one of said simultaneously addressable electrodes, said signal processing element being responsive to pixel density values associated with electrodes other than said selected electrode to determine a corrected pixel density value associated with said selected electrode.

4. A method of correcting pixel density, comprising the steps of:

(a) processing a signal containing pixel density values conveyed to a printing head of an electrocoagulation printing apparatus that includes a plurality of simultaneously addressable electrodes to determine a corrected pixel density value associated with a selected one of said plurality of simultaneously addressable electrodes in dependence of pixel density values associated with electrodes other than said selected electrode; and
(b) outputting the corrected pixel density value.

5. A film of electrocoagulation printing ink containing a coagulated polymer with embedded graphical data, said film including a matrix of localized coagulation sites, said polymer being coagulated to a selected degree at each said site, said matrix comprising a row of contiguous sites that extend along an imaginary straight line.

FIG. 1
PRIOR ART

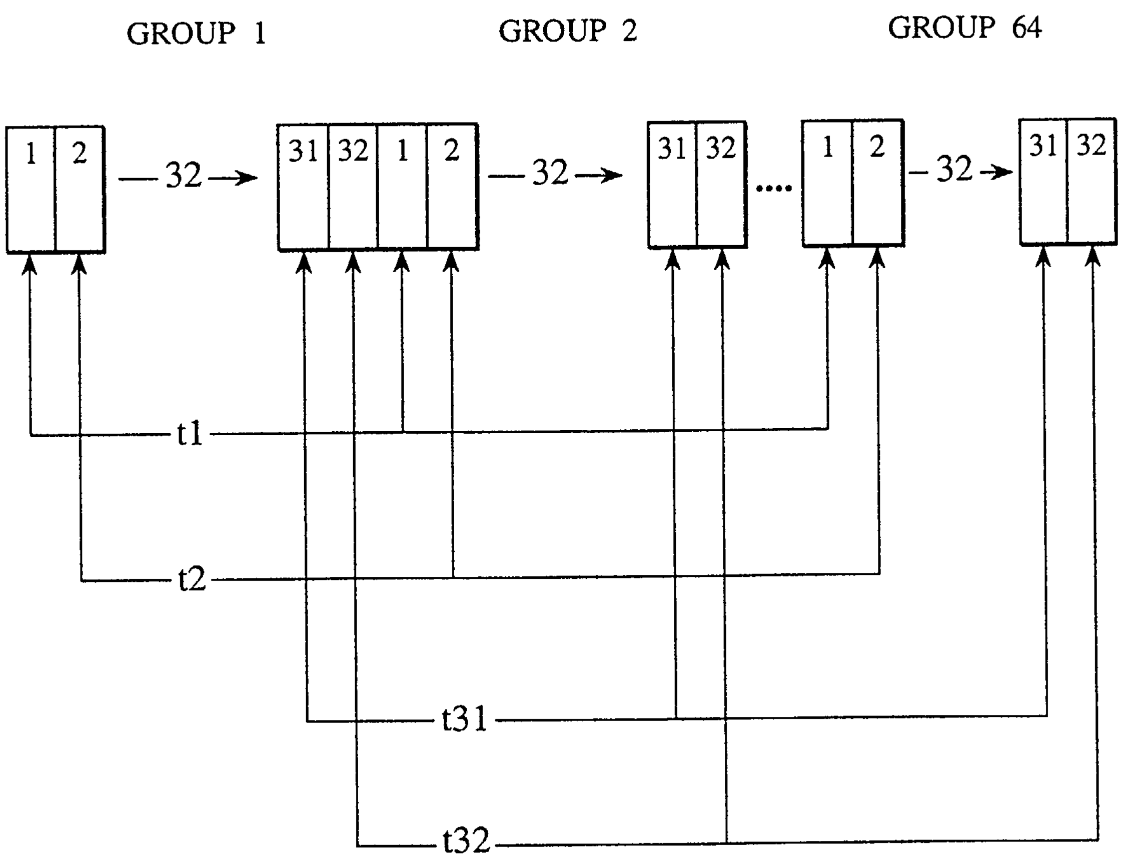


FIG. 2
PRIOR ART

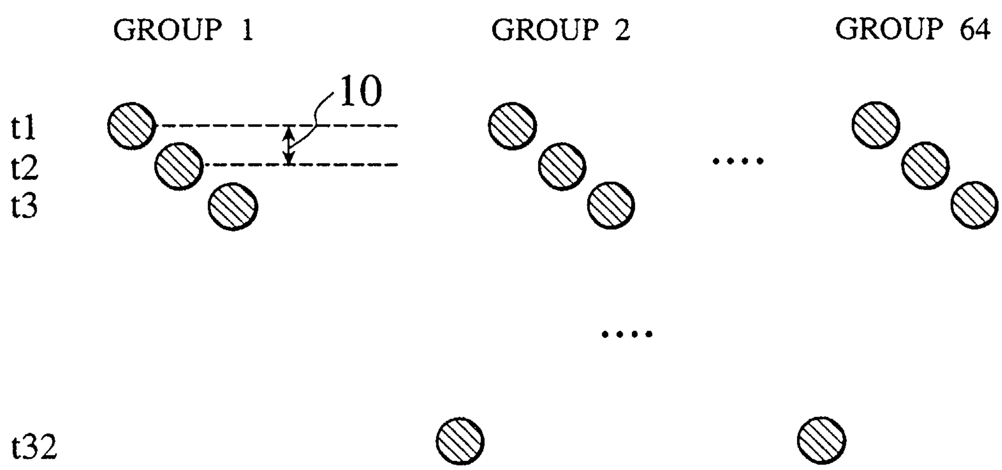


FIG. 3

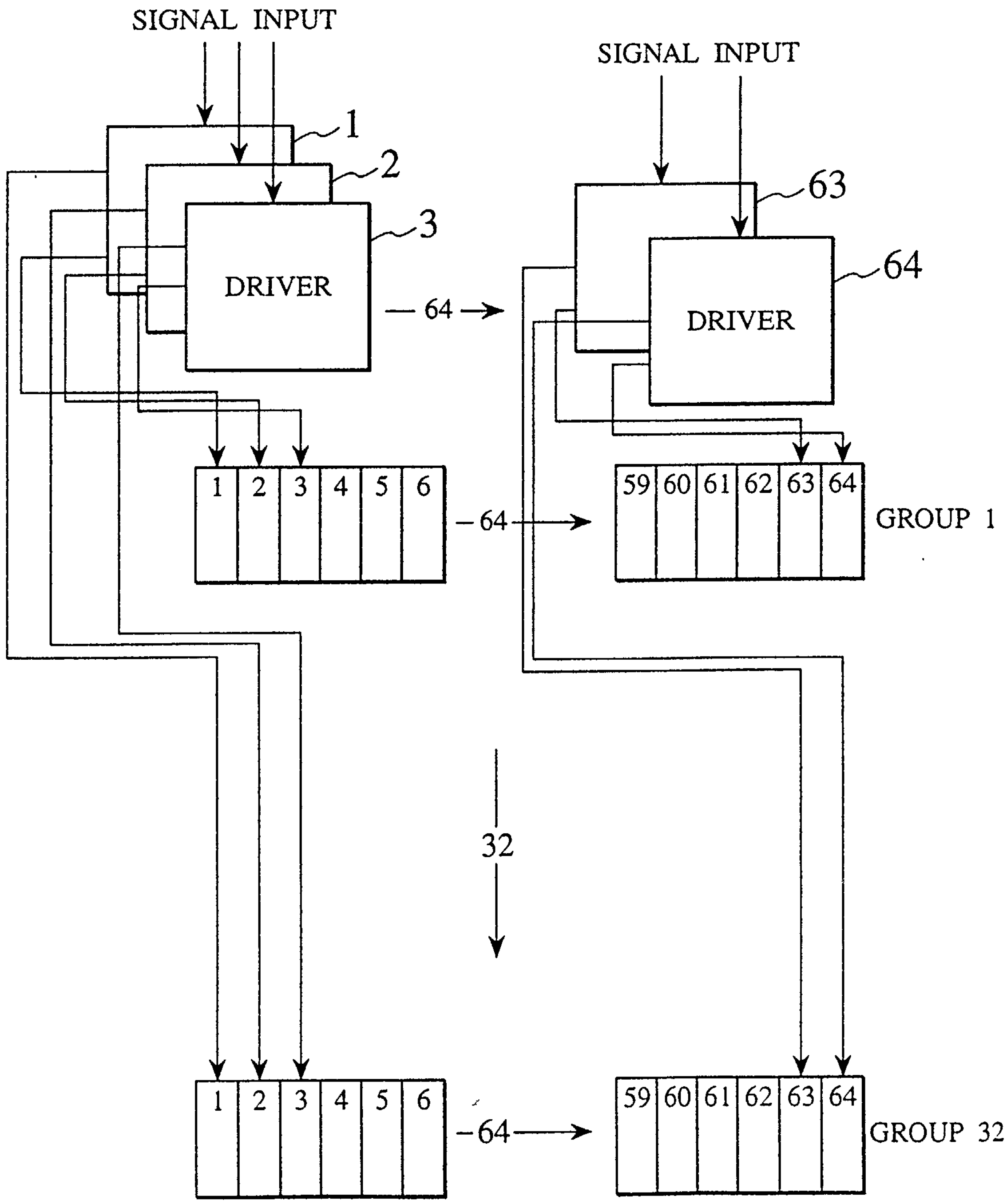

SIGNAL INPUT
1
2
3
DRIVER
64
SIGNAL INPUT
63
64
DRIVER
1 2 3 4 5 6
64
59 60 61 62 63 64
GROUP 1
32
1 2 3 4 5 6
64
59 60 61 62 63 64
GROUP 32

FIG. 4

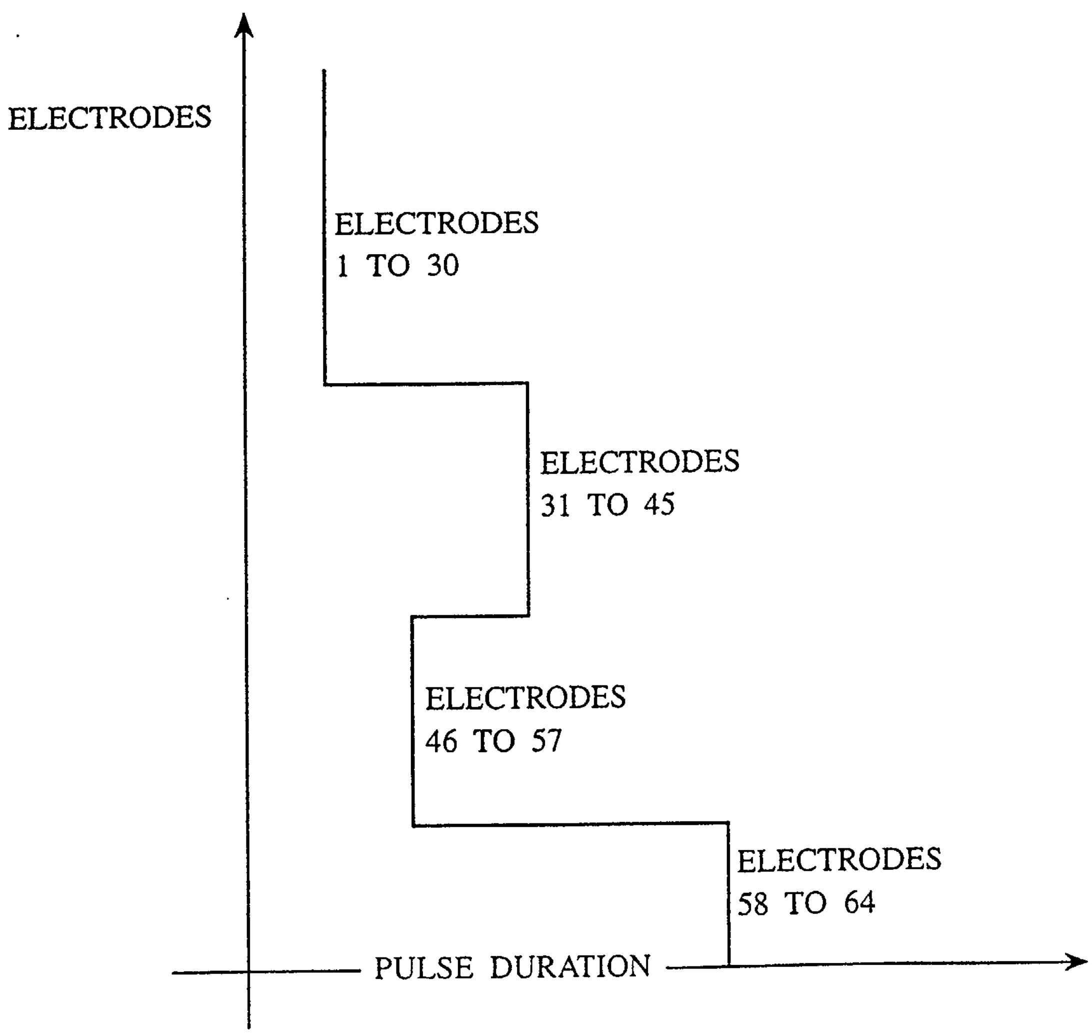

ELECTRODES
ELECTRODES
1 TO 30
ELECTRODES
31 TO 45
ELECTRODES
46 TO 57
ELECTRODES
58 TO 64
PULSE DURATION

FIG. 5

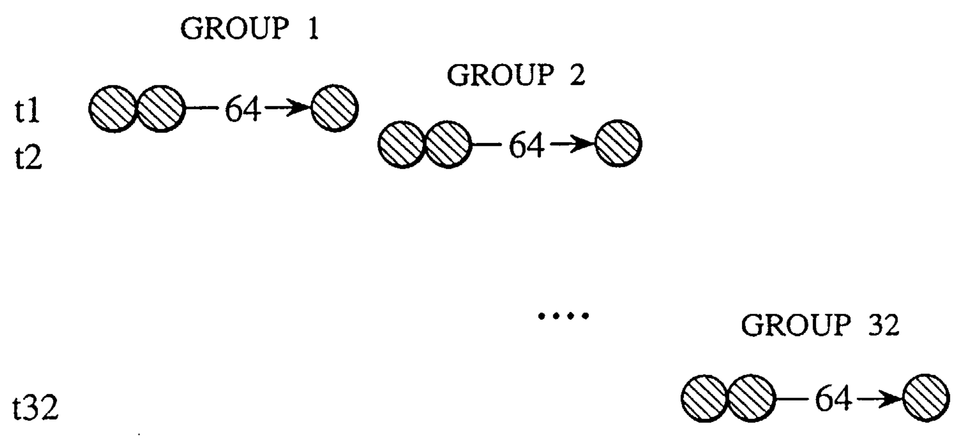


FIG. 6

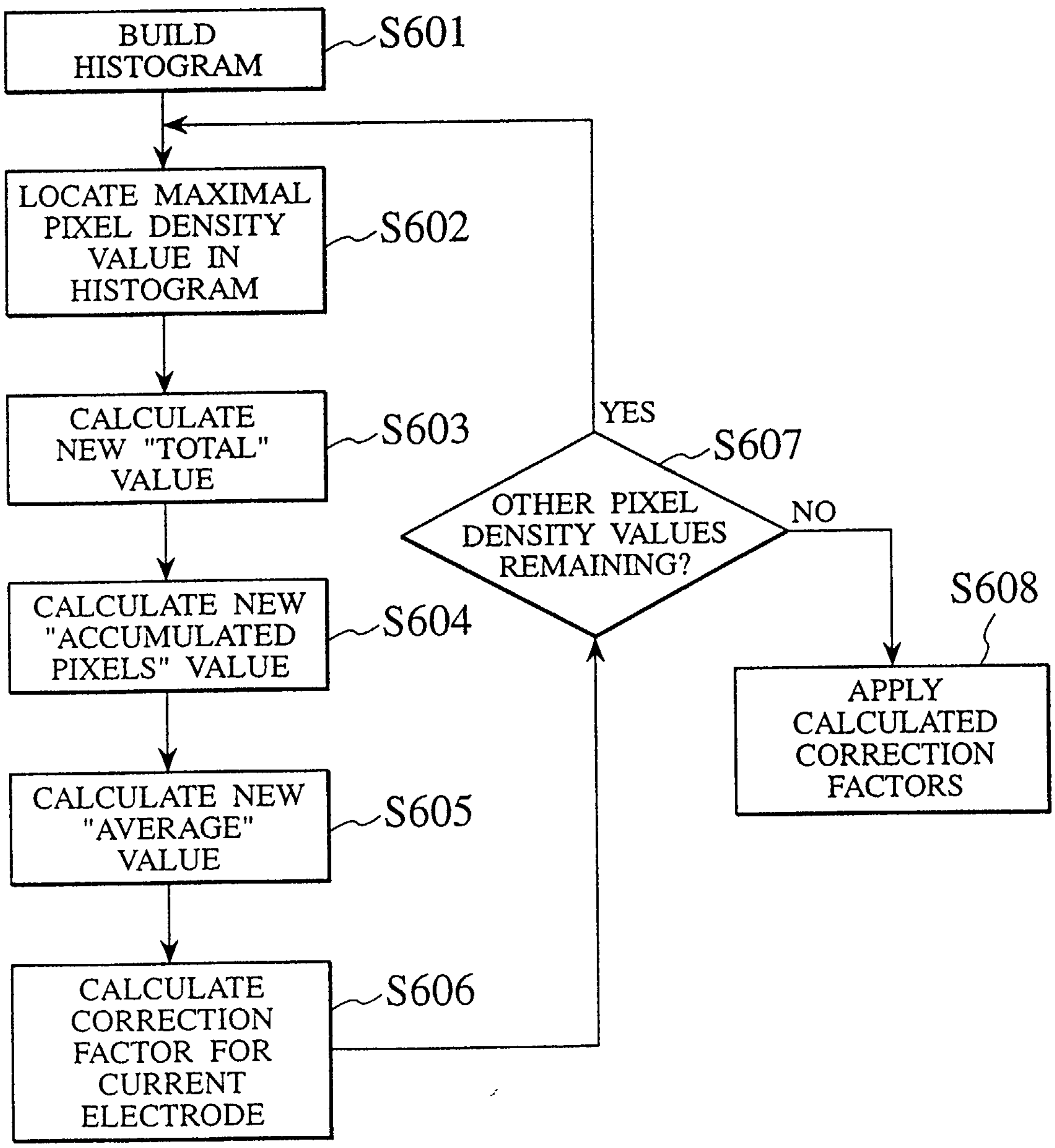

BUILD HISTOGRAM
S601
LOCATE MAXIMAL PIXEL DENSITY VALUE IN HISTOGRAM
S602
CALCULATE NEW "TOTAL" VALUE
S603
CALCULATE NEW "ACCUMULATED PIXELS" VALUE
S604
CALCULATE NEW "AVERAGE" VALUE
S605
CALCULATE CORRECTION FACTOR FOR CURRENT ELECTRODE
S606
YES
S607
OTHER PIXEL DENSITY VALUES REMAINING?
NO
S608
APPLY CALCULATED CORRECTION FACTORS

FIG. 7A

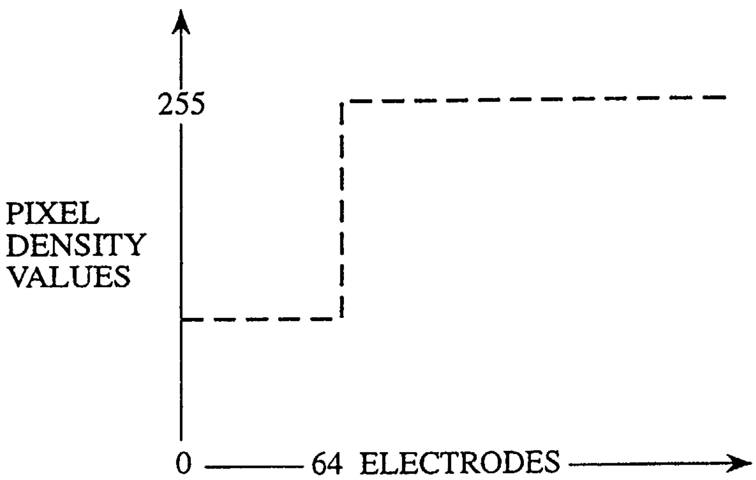

255
PIXEL
DENSITY
VALUES
0
64 ELECTRODES

FIG. 7B

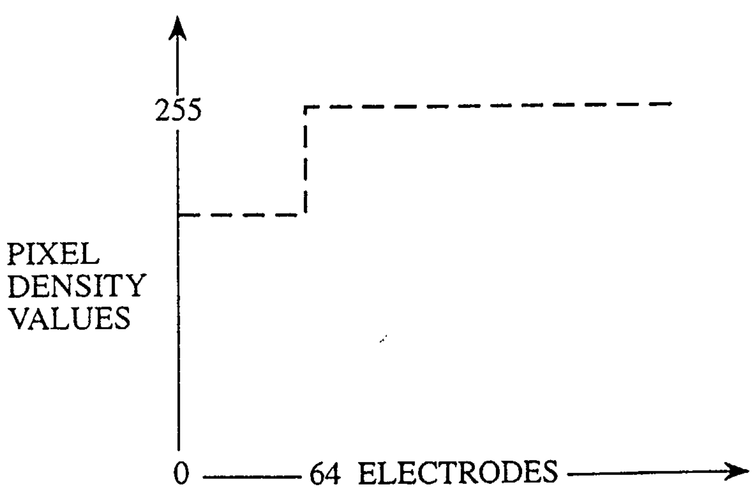

255
PIXEL
DENSITY
VALUES
0
64 ELECTRODES

FIG. 7C

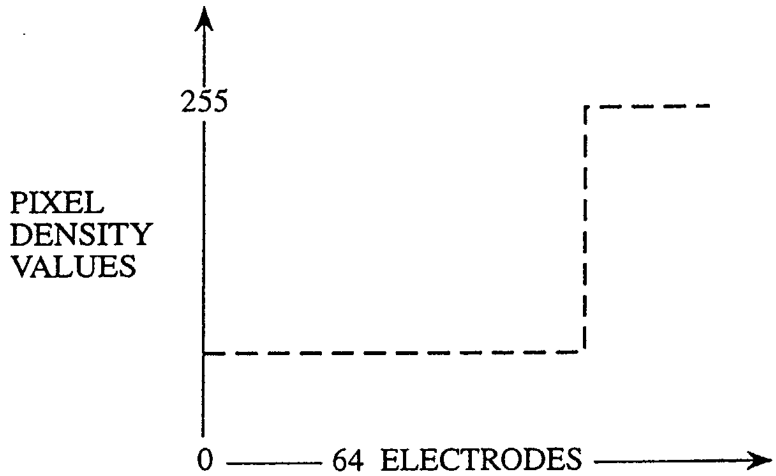

255
PIXEL
DENSITY
VALUES
0
64 ELECTRODES

FIG. 7D

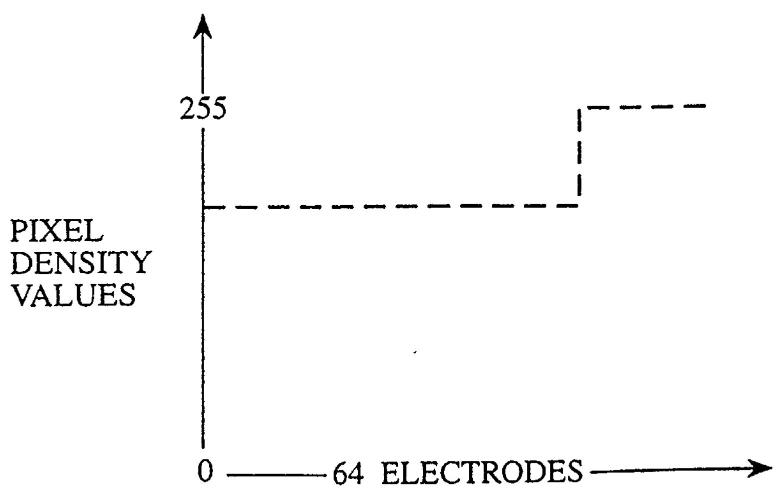

255
PIXEL
DENSITY
VALUES
0
64 ELECTRODES

FIG. 8

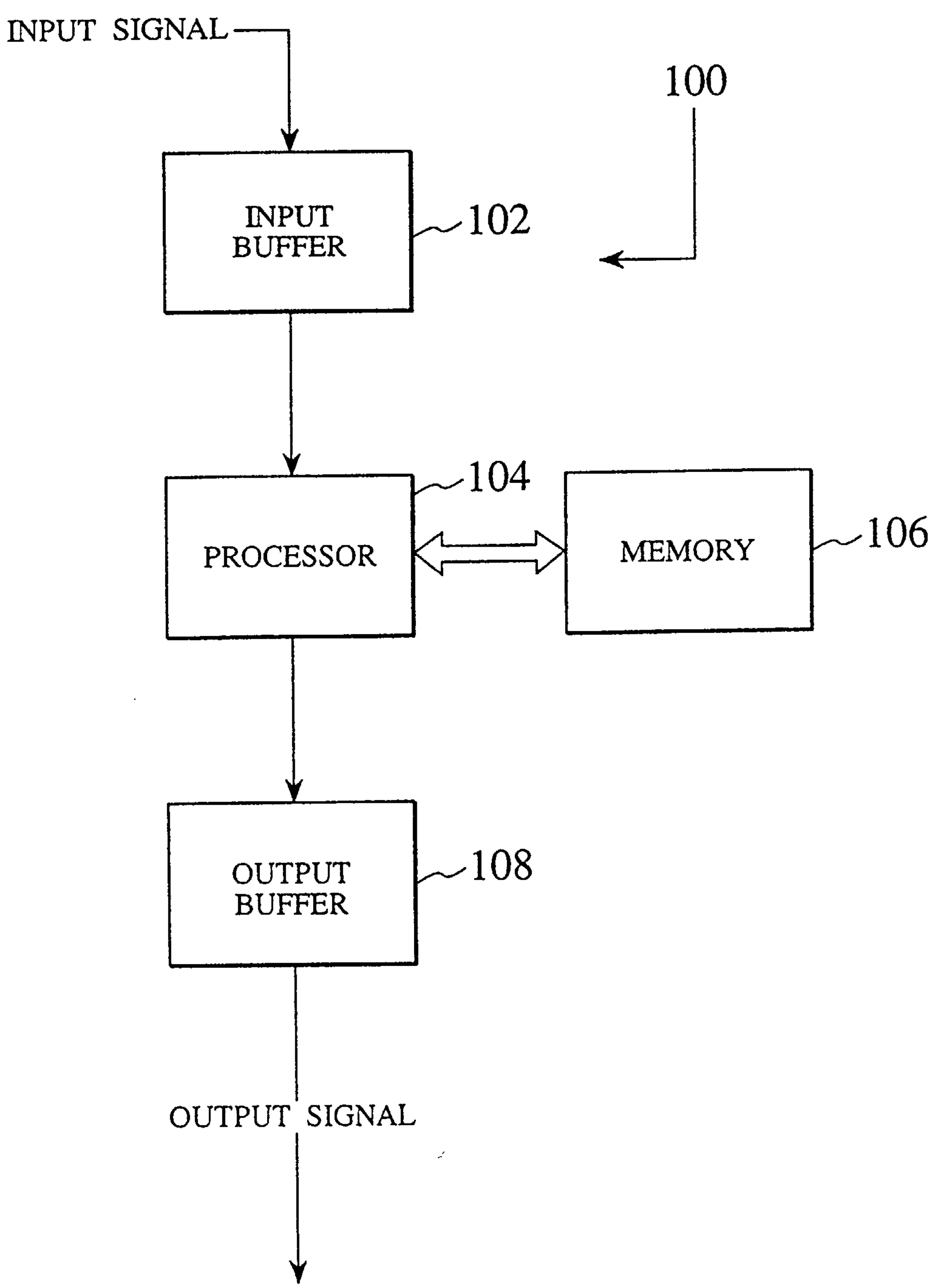
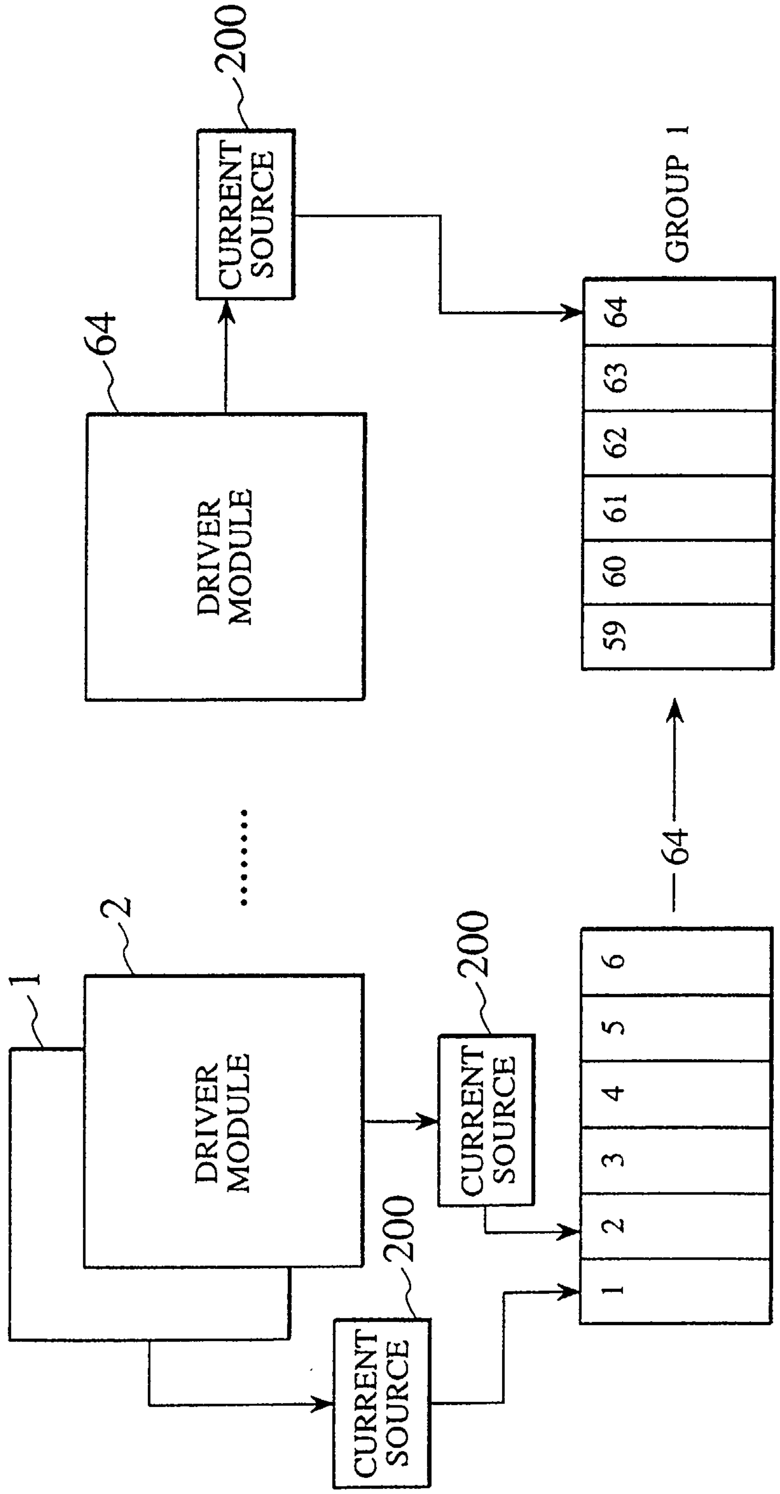

INPUT SIGNAL
100
INPUT BUFFER
102
104
PROCESSOR
MEMORY
106
OUTPUT BUFFER
108
OUTPUT SIGNAL

FIG. 9


DRIVER MODULE
DRIVER MODULE
CURRENT SOURCE
CURRENT SOURCE
CURRENT SOURCE
1
2
64
200
200
200
GROUP 1
1
2
3
4
5
6
59
60
61
62
63
64
64
....

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 01 6248

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,A	US 4 895 629 A (CASTEGNIER ADRIEN ET AL) 23 January 1990 (1990-01-23) * column 8, line 46 - column 18, line 5; figures 1,23 *	1-5	B41J2/39 B41C1/10
A	WO 97 30379 A (TOYO INK MFG CO) 21 August 1997 (1997-08-21) * abstract; figure 4 *	1-5	
A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 343 (M-741), 14 September 1988 (1988-09-14) & JP 63 104848 A (MATSUSHITA ELECTRIC IND CO LTD), 10 May 1988 (1988-05-10) * abstract *	1-5	
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 022 (M-354), 30 January 1985 (1985-01-30) & JP 59 167280 A (RICOH KK), 20 September 1984 (1984-09-20) * abstract *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B41C
B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 August 2002	De Groot, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 02 01 6248

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21-08-2002

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			EP	0467904	A1	29-01-1992
			JP	2764065	B2	11-06-1998
			JP	4504688	T	20-08-1992
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			EP	0822462	A1	04-02-1998
			WO	9730379	A1	21-08-1997
JP 63104848	A	10-05-1988	NONE			
JP 59167280	A	20-09-1984	JP	1796288	C	28-10-1993
			JP	5005666	B	22-01-1993

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