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(54) **A device for direct electrostatic printing with a conventional printhead structure and an AC-voltage coupled to both the toner bearing surface and the control electrodes**

(57) A DEP device wherein printing is realised by applying a first AC-voltage upon a surface bearing charged toner particles with an amplitude that is not sufficient for toner particles to pass through the printing apertures, and enhancing said AC-field present between the toner bearing surface and the printhead structure, by applying a second AC-voltage (which is out of phase with respect to the first AC-voltage) upon the control electrodes, so that in an image wise manner the AC-field between the toner bearing member and the control electrodes can be switched from an ON condition in which toner particles can pass the printing apertures, to an OFF condition in which said toner particles are prevented from passing said printing apertures.

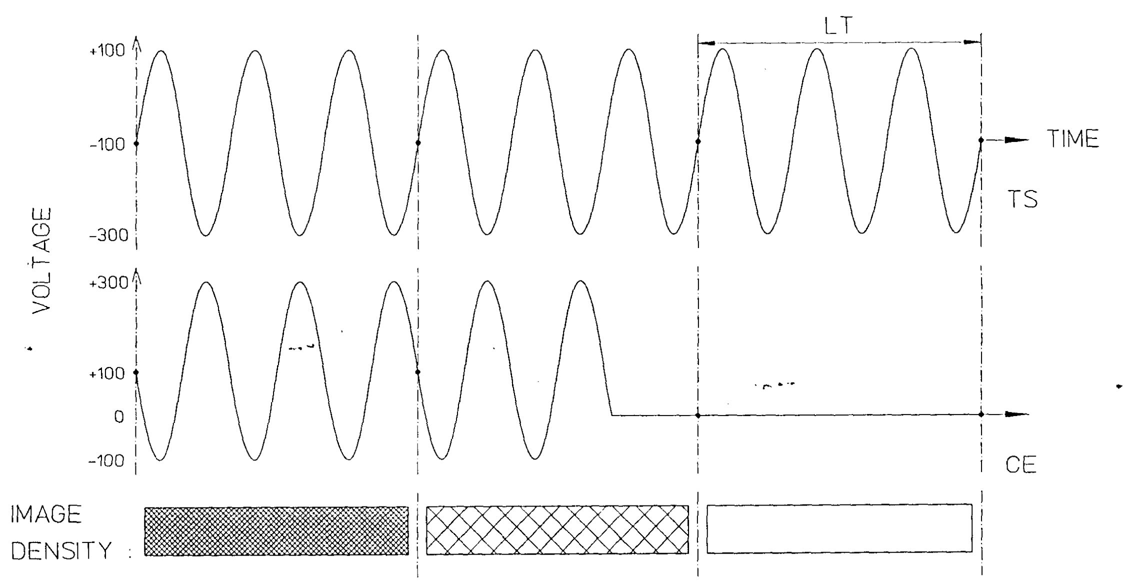

Fig 3

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Description

FIELD OF THE INVENTION

[0001] This invention relates to a method and an apparatus used in the process of electrostatic printing and more particularly in Direct Electrostatic Printing (DEP). In DEP, electrostatic printing on an image receiving substrate is performed by creating a flow of toner particles from a toner bearing surface to the image receiving substrate and image-wise modulating the flow of toner particles by means of an electronically addressable printhead structure.

BACKGROUND OF THE INVENTION

[0002] In DEP (Direct Electrostatic Printing) the toner or developing material is deposited directly in an image-wise way on a receiving substrate, the latter not bearing any image-wise latent electrostatic image. The substrate can be an intermediate endless flexible belt (e.g. aluminium, polyimide etc.). In that case the image-wise deposited toner must be transferred onto another final substrate. Preferentially the toner is deposited directly on the final receiving substrate, thus offering a possibility to create directly the image on the final receiving substrate, e.g. plain paper, transparency, etc. This deposition step is followed by a final fusing step.

[0003] This makes the method different from classical electrography, in which a latent electrostatic image on a charge retentive surface is developed by a suitable material to make the latent image visible. Further on, either the powder image is fused directly to said charge retentive surface, which then results in a direct electrographic print, or the powder image is subsequently transferred to the final substrate and then fused to that medium. The latter process results in an indirect electrographic print. The final substrate may be a transparent medium, opaque polymeric film, paper, etc.

[0004] DEP is also markedly different from electrophotography in which an additional step and additional member is introduced to create the latent electrostatic image. More specifically, a photoconductor is used and a charging/exposure cycle is necessary.

[0005] A DEP device is disclosed in e.g. **US-A-3 689 935** This document discloses an electrostatic line printer having a multi-layered particle modulator or printhead structure comprising :

- a layer of insulating material, called isolation layer ;
- a shield electrode consisting of a continuous layer of conductive material on one side of the isolation layer ;
- a plurality of control electrodes formed by a segmented layer of conductive material on the other side of the isolation layer ; and
- at least one row of apertures.

[0006] Each control electrode is formed around one aperture and is isolated from each other control electrode.

[0007] Selected electric potentials (only DC-potentials) are applied to each of the control electrodes while a fixed potential is applied to the shield electrode. An overall applied propulsion field between a toner delivery means and a support for a toner receiving substrate projects charged toner particles through a row of apertures of the printhead structure. The intensity of the particle stream is modulated according to the pattern of potentials applied to the control electrodes. The modulated stream of charged particles impinges upon a receiving substrate, interposed in the modulated particle stream. The receiving substrate is transported in a direction orthogonal to the printhead structure, to provide a line-by-line scan printing. The shield electrode may face the toner delivery means and the control electrodes may face the receiving substrate. A DC-field is applied between the printhead structure and a single back electrode on the receiving substrate. This propulsion field is responsible for the attraction of toner to the receiving substrate that is placed between the printhead structure and the back electrode.

[0008] One of the problems with this type of printing devices is that charged toner particles can accumulate upon the printhead structure and in the printing apertures. Due to this problem the achievable printing density does not remain constant in the time, while the charged toner particles accumulated on the printhead structure may change the electrical field wherein the charged toner particles are propelled towards the substrate and the toner particles accumulated in the printing apertures can physically block the toner passage.

[0009] This problem of clogging of the printing apertures has been addressed in several ways, there have been disclosed ways and means to avoid the clogging and ways and means to clean the printhead and the printing apertures.

[0010] A first way disclosed to avoid the clogging of printing apertures relies on the design of the printhead structure, the printing apertures or both. Such means have been disclosed in, e.g., **US-A-4 876 561, US-A-5 307 092, EP-A-780 740, US-A-5 625 392** , etc.

[0011] Another way to avoid the clogging of printing apertures and the smudging of the printhead that was disclosed relies on tuning the charge of the toner particles that are used. In, e.g., **US-A-4 755 837** and **US-A-4 814 796** it is disclosed that the presence of Wrong Sign Toner (WST) is the main cause of accumulation of toner particles upon said printhead structure and in the printing apertures.

[0012] Also mechanical ways to prevent clogging or to clean the printing apertures have been disclosed. In, e.g., **US-A-5 153 611**, **US-A-5 202 704, US-A-5 233 392** it is disclosed to prevent clogging of the printing apertures by using an ultrasonic vibration applied to the printhead. In **US-A-5 283 594** the level of vibration applied to the printhead is different during writing time and cleaning time. In **US-A-5 293 181** the printhead is vibrated in such a way that a mechanical propagating wave is created.

[0013] Electrical means to clean the printhead structure have been disclosed in, e.g., **US-A-4 491 855, US-A-4 478 510, US-A-4 903 050, US-A-4 755 837, US-A-5 095 322** etc.

[0014] The ways to prevent clogging as described above, do all more or less solve that problem, but the methods entail their own drawbacks. The electrical means to clean the printhead structure require frequently the use of high voltage and/or electric spark generators, which entails that the DEP apparatus incorporating electric cleaning means are more complicated and/or expensive than DEP device not needing such cleaning provisions. The same goes for the DEP device including ultrasonic vibration as cleaning means for the printhead structure. When the design of the printhead has to be adapted for avoiding clogging, the degrees of freedom in constructing the printhead and the printing apertures become smaller. When thin printhead structures with relatively wide printing apertures are used, the strength of the printhead structures as well as the possible resolution are diminished. Using an edge electrode as printhead structure as described in **US-A-5 625 392** solves the problem of clogging, but suffers from the drawback that, in order to obtain a good image contrast between image parts of low density and image parts of high density, the overall applied propulsion field between the toner source and the receiver on the back electrode must be set to a rather low value, so that per unit of time only a moderate amount of toner particles can be attracted so that only a moderate printing speed is possible when high optical density is desired.

[0015] DEP devices of the prior art mostly operate by applying a large propulsion field (DC-field) between the surface of a toner source and a back electrode wherein charged toner particles migrate from the toner source towards the back electrode. A printhead structure with printing apertures coupled to control electrodes is placed between the toner source and the back electrode for image-wise controlling the migration of the toner particles. In order to have enough toner particles entering that field an AC-voltage source is connected the surface of the toner source and an AC-field is present over the gap between the toner source and the printhead structure. In this case the printhead structure with printing apertures coupled to control electrodes, that is placed between the toner source and the back electrode, allows the toner particles to pass the printing apertures unless a DC-voltage counteracting the propulsion field between toner source and back electrode is applied to the control electrodes. Typical disclosures where an AC-voltage is applied to the toner source and the passage of toner particles governed by DC-voltages on the control electrodes are e.g. **US-A-4 491 855**, **EP-A-769 384** and **EP-A-0 884 190**. In the first disclosure it is claimed that applying an AC-field to the toner bearing member is advantageous for preventing toner adhesion to said printhead structure, but the main benefit comes from the enhanced toner flux which can provide faster printing. In the second disclosure it is disclosed to synchronise the AC-potential applied to the toner source to the line-time used to apply a passing or blocking DC-potential to the control electrodes. In the third disclosure, it is disclosed to apply a varying signal to the control electrode in order to create an AC-effect in the beginning of each line-time. All these descriptions do provide effective means for enhancing the toner flux through the printing apertures, but due to the presence of DC-voltage counteracting the propulsion field, the change of sticking of toner particles to the printhead structure is rather enhanced than diminished. When in such a DEP device high speed printing is desired, the AC-field applied to the surface of the toner source has to be made very strong so that a large number of toner particles enters the propulsion field. But then the DC-voltage counteracting the propulsipn field has to be quite high (entailing a higher risk of toner adhesion) or it is impossible to block the apertures completely so that fog is formed.

[0016] In **EP-A-911 706** a DEP device is disclosed wherein the passing or blocking of the toner particles is not realised by applying a DC-voltage counteracting the propulsion field to the control electrodes, but by modulating the strength and/or the application time of the AC-field over the gap between the toner source and the printhead structure. This configuration has as major advantage that the clogging of the printing apertures and the adhesion of toner particles to the printhead are avoided and the necessity of a large DC-voltage on the control electrodes is diminished. This is especially interesting since no special measures have to be taken to avoid clogging and toner adhesion. The AC-voltage on the control electrodes is switched by switching IC's that can not withstand an unlimited amplitude of the AC-voltage. Typical IC's (SUPERTEX HV505, 507, 330,.. (trade names)) can withstand at most 400 V peak to peak the AC-field. This brings the problem that the toner flux can't be very high under and that thus for a given printing speed the resulting image density is rather low whereas the density can only be enhanced by lowering the printing speed.

[0017] Thus there is still a need for further improved DEP devices having low or no clogging of the printing apertures, low or no toner adhesion that are stable in time. Especially a DEP device wherein low or no clogging and low or no toner adhesion is combined with high printing speed is still highly desired.

OBJECTS AND SUMMARY OF THE INVENTION

[0018] It is an object of the invention to provide a DEP device, i.e. a device for direct electrostatic printing that can print at high speed with low or no clogging of the printing apertures and low or no toner adhesion and with high maximum density and with a high degree of density resolution (i.e. for producing an image comprising a high amount of differentiated density levels) and spatial resolution.

[0019] A further object of the invention is to provide a DEP device that can be used with a wide variety of types of toner particles, and that can print at high speed with low clogging of the control electrodes, with high maximum density and with a printing quality that is constant over a long period of time.

[0020] A still further object of the invention is to provide a DEP device that operates with moderate voltages and relatively inexpensive switching IC's and that can print at high speed with low or no clogging of the printing apertures and low or no toner adhesion and with high maximum density and with a high degree of density resolution (i.e. for producing an image comprising a high amount of differentiated density levels) and spatial resolution.

[0021] Further objects and advantages of the invention will become clear from the detailed description herein after.

[0022] The objects of the invention are realised by providing a device for direct electrostatic printing comprising

- a means for delivering charged toner particles, said means having a toner bearing surface coupled to a means for applying an AC-voltage, AC2, with an amplitude, AM_{AC2}, and a frequency, f_{AC2},
- a means for making charged toner particles migrate away from said surface to an image receiving substrate, placed opposite to said surface,
- a printhead structure, having printing apertures and control electrodes associated therewith, placed between said toner bearing surface and said image receiving substrate, leaving a gap (d) between said toner bearing surface and said control electrodes,

characterised in that

- said control electrodes are coupled to a second means for applying an AC-voltage, AC3, being between 90° and 270° out of phase with respect to said AC-voltage, AC2, and having an amplitude, AM_{AC3}, and a frequency, f_{AC3}, wherein said amplitude, AM_{AC3}, being chosen so that $1/3 \leq AM_{AC2}/AM_{AC3} \leq 3$, and in that
- a means is placed between said control electrodes and said means for generating said AC-voltage, AC3, for selectively switching said AC-voltage, AC3, in accordance with image data to a value stopping said toner particles from passing said printing apertures and a value allowing said toner particles to pass said printing apertures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

Fig. 1 shows electric voltages applied in a prior art printing device according to the second embodiment of the device described in **EP-A-911 706** for printing maximum density, middle density and no density

Fig. 2 shows electric voltages applied in a prior art printing device according to the first embodiment of the device described in **EP-A-911 706** for printing maximum density, middle density and no density

Fig. 3 shows electric voltages applied in a first embodiment of a printing device according to this invention for printing maximum density, middle density and no density

Fig. 4 shows electric voltages applied in a second embodiment of a printing device according to this invention for printing maximum density, middle density and no density

Fig. 5 shows schematically a DEP device according to this invention.

Fig. 6 shows an electrical diagram for generating the essentially out of phase AC-voltages applied to toner bearing surface and control electrodes.

DEFINITIONS

[0024]

- The wording "Toner bearing surface" is used throughout this document to indicate the surface of the means for delivering toner particles from where a flow of toner particles to the image receiving substrate originates.
- The wording "OFF-period" is used to indicate the time during which the control electrode is kept at an electric potential for blocking the passage of charged toner particles through the printing apertures controlled by said control electrode.
- The wording "ON-period" is used to indicate the time during which the control electrode is kept at an electric potential for letting charged toner particles pass through the printing apertures controlled by said control electrode.

DETAILED DESCRIPTION OF THE INVENTION

[0025] It is known in the art of DEP (direct electrostatic printing), as described in the background art section above, that, such devices mostly operate by applying a large propulsion field (DC-field) between the surface of a toner source and a back electrode wherein charged toner particles migrate from the toner source towards the back electrode. A printhead structure with printing apertures coupled to control electrodes is placed between the toner source and the back electrode for image-wise controlling the migration of the toner particles. In order to have enough toner particles entering that field an AC-voltage source is connected the surface of the toner source and an AC-field is present over the gap between the toner source and the printhead structure. In this case the printhead structure with printing apertures coupled to control electrodes, that is placed between the toner source and the back electrode, allows the toner particles to pass the printing apertures unless a DC-voltage counteracting the propulsion field between toner source and back electrode is applied to the control electrodes. When in such a DEP device high speed printing is desired, the AC-field applied to the surface of the toner source has to be made very strong so that a large number of toner particles enters the propulsion field. But then the DC-voltage counteracting the propulsion field has to be quite high or it is impossible to block the apertures completely so that fog is formed. Levelling or reversing the propulsion field rapidly leads to toner adherence upon the printhead structure and to the wall of the printing apertures in the insulating material of the printhead structure, this leads to clogging of the printing apertures and thus to image artefacts and poor print quality, e.g., white dots or lines in even density patches due to the fact that some printing apertures are totally clogged.

[0026] It was described in **EP-A-0 911 706** that instead of using DC-fields to block or pass the continuous toner flux, it is also possible to tune an AC-effect on every control electrode around a printing aperture in image-wise way so that toner particles are attracted in the propulsion field when needed. This was done by modulating an AC-field over the gap between the toner bearing surface and the printhead structure to a value is strong enough to pass toner particles through the printing apertures (the ON-condition), and to a value that is not strong enough for to pass toner particles through the printing apertures (the OFF-condition). Commercially available control IC's become very expensive in the high voltage range and are only easily available in the 300 to 400 V range, said description in **EP-A-911 706** can only work with rather low switching voltages, and as a result with rather low printing speeds.

[0027] Whereas, however, the way of image-wise modulating the flow of charged toner particles as described in EP-A-911 706, has such a beneficial effect on the risk of clogging the printing apertures (risk of clogging almost non-existent) and toner adhesion upon said printhead structure, it would be a step forward in the design of DEP devices when this system could be adapted for a higher printing speed (high printing speed means a printing speed from 3 m/min, i.e. 10 DIN A4 sheets portrait, on). This is the more so since the avoidance of clogging and toner adhesion is in a system, as described in EP-A-911 706, realised without special design of the printhead structure, without means to vibrate the printhead, without the need for spark discharges between the printing cycles, etc. Thus the degrees of freedom in producing a DEP device wherein the image-wise deposition of toner particles proceeds by varying an AC-field and by detaching the toner particles from the surface of the toner source and bringing them in the propulsion field only when needed are enhanced over prior art devices where a continuous flow of toner particles is image-wise blocked by a DC-voltage on the control electrodes.

[0028] It was now found by the inventors that the advantages of the devices as disclosed in EP-A-911 706 could be kept and the printing speed of them considerably enhanced when on the toner bearing surface a first AC-voltage was continuously applied, but resulting in a field strength too low to propel the toner particles through the printing apertures in the propulsion field extending from the toner bearing surface to the image receiving member and on the control electrodes a second AC-voltage was applied with a modulation and frequency essentially equal to that of the first AC-voltage and the two AC-voltages were out of phase by between 90° and 270° (both limits included). The beneficial effect becomes more pronounced when the two AC-voltages were out of phase by between 135° and 225°. It is preferred to adjust both the AC-voltage so that they are between 160° and 200° out of phase. By doing so a DEP device wherein the toner bearing surface and the printhead structure were spaced 100 µm with printing speed of 5 m/min could be manufactured using existing relatively inexpensive switching IC 's, whereas the printing speed, for giving the same maximum optical density in the device according to EP-A-911 706, wherein the toner bearing surface and the printhead structure were only spaced 50 µm, was only 2 m/min. Thus since the distance between the toner bearing surface and the printhead structure can be increased, the degrees of freedom in constructing the device are further enhanced.

[0029] In figure 1, the voltages applied in the second embodiment of the prior art DEP device according to EP-A-911 706 are shown in the case of using negatively charged particles. The figure shows a printing time for 3 line-times for printing different densities through one printing aperture, from left to right the control electrode (CE) in on-condition for the entire line-time printing D_{max}, then the control electrode in on-condition for 70 % of the line-time printing an intermediate density and then the control electrode in off-condition for the entire line-time printing D_{min}. During the three line-times, the toner bearing surface (TS) is connected to ground potential, (0 V DC). During the first line-time the control electrode is connected for the entire line-time to an AC-voltage of 400 V peak to peak with a DC-offset of + 100 V. This has as a consequence that an AC-field exists over the gap (that in the prior art is maximum 50 µm wide) between the toner bearing surface and the printhead structure and has a value strong enough to pass toner particles through the printing apertures during the entire line-time. During the second line-time the control electrode is connected, for only 70 % of the line-time to an AC-voltage of 400 V peak to peak with a DC-offset of + 100 V, for the remaining 30 % of the line-time the control electrode is grounded. This has as a consequence that an AC-field exists over the gap between the toner bearing surface and the printhead structure and has a value strong enough to pass toner particles through the printing apertures exists during the 70 % of the line-time and no AC field exists for the last 30 % of the line-time. During the third line time the control electrode is grounded for the entire line-time and no AC field exists.

[0030] In figure 2, the voltages applied in the first embodiment of the prior art DEP device according to EP-A-911 706 are shown in the case of using negatively charged particles. The figure shows a printing time for 3 line-times for printing different densities through one printing aperture, from left to right the control electrode in on-condition for the entire line-time printing D_{max}, then the control electrode in on-condition for 50 % of the line-time printing an intermediate density and then the control electrode in off-condition for the entire line-time printing D_{min}. During the three line-times, the toner bearing surface (TS) is connected to an AC-voltage of 400 V peak to peak with a DC-offset of - 100 V. During the first line-time the control electrode (CE) is grounded for the entire line-time. This has as a consequence that an AC-field exists over the gap (that is maximum 50 µm wide) between the toner bearing surface and the printhead structure and has a value strong enough to pass toner particles through the printing apertures during the entire line-time. During the second line-time the control electrode is grounded for only 50 % of the line-time so that for only 70 % of the line-time an AC-field exists over the gap (that in the prior art is maximum 50 µm wide) between the toner bearing surface and the printhead structure and has a value strong enough to pass toner particles through the printing apertures. For the remaining 50 % of the line-time the control electrode is connected to an AC-voltage of 400 V peak to peak with a DC-offset of - 100 V. The AC-field on the control electrode is in phase with the AC-voltage on the toner bearing surface, this has as a consequence that, when no net AC-field exists over the gap between the toner bearing surface and the printhead structure for the last 50 % of the line-time. It is clear from figure 2 that when the AC-voltage on the toner bearing surface has a value of - 300 V, strongly repelling negatively charged toner particles, then also the AC-voltage on the control electrode has a value of - 300 V, strongly repelling negatively charged toner particles : thus the toner particles do not move from the toner bearing surface During the third line time the control electrode is for the entire line-time to an AC-voltage of 400 V peak to peak with a DC-offset of -100 V, the AC-field on the control electrode is in phase with the AC-voltage on the toner bearing surface, this has as a consequence that an AC-field exists over the gap between the toner bearing surface and the printhead structure no AC field exists.

[0031] In figure 3, the voltages applied to the control electrode (CE) and the toner bearing surface (TS) in a first embodiment of a DEP device according to this invention are shown (also explained with negatively charged toner particles, as a matter of course when the polarities of the voltage are reversed, the system can work with positively charged toner particles). The figure shows a printing time for 3 line-times for printing different densities through one printing aperture, from left to right the control electrode (CE) in on-condition for the entire line-time printing D_{max}, then the control electrode in on-condition for 70 % of the line-time printing an intermediate density and then the control electrode in off-condition for the entire line-time printing D_{min}. During the three line-times, the toner bearing surface (TS) is connected to a sinusoidal AC-voltage of 400 V peak to peak with a DC-bias of - 100 V. During the first line-time the control electrode is connected for the entire line-time to an AC-voltage of 400 V peak to peak with a DC-offset of + 100 V. Both AC voltage are out of phase by 180 °, so that when the voltage on the toner bearing surface is - 300 V, i.e. strongly repelling negatively charged toner particles, the voltage on the control electrode is + 300 V, i.e. strongly attracting negatively charged toner particles, thus the effect is that the AC-voltage on the control electrode amplifies the influence of the AC voltage on the toner bearing surface. During the first line-time the control electrode is connected for 70 % of the line-time to an AC-voltage of 400 V peak to peak with a DC-offset of + 100 V. This means that the influence AC-voltage on the toner bearing surface (TS) is only amplified for 70 % of the line time by the AC-voltage on the control electrode and only 70 % of D_{max} is printed. During the third line time the control electrode is grounded for the entire line-time and no amplification of the influence of the AC-voltage on the toner bearing surface is present, no toner particles pass the printing aperture and Dmin is printed.

[0032] In figure 4, the voltages applied to the control electrode (CE) and the toner bearing surface (TS) in a second embodiment of a DEP device according to this invention are shown (also explained with negatively charged toner particles, as a matter of course when the polarities of the voltage are reversed, the system can work with positively charged toner particles). In this figure both the AC-voltage on the toner bearing surface and on the control electrode are square waves. The AC voltage on the toner bearing surface has a peak to peak voltage of 400 V, with a DC-offset of 0 volts, and the AC voltage on the toner bearing surface has a peak to peak voltage of 400 V, with a DC-offset of + 200 volts. Basically the embodiment shown in figure 4 functions in the same way as the one shown in figure 3.

[0033] It was found that using AC-voltages, AC2 and AC3, having a square-wave form instead of a sinusoidal wave form did give higher printing density, thus having a square-wave form for AC2 and AC3 is a preferred embodiment of this invention.

[0034] It was found that the peak to peak voltage, i.e. the amplitude, of the AC-voltage, AC2, on the toner bearing surface, AM_{AC2}, and the peak to peak voltage, i.e. the amplitude, of the AC-voltage, AC3, on the control electrodes ,AM_{AC3}, are preferably such that $1/3 \leq AM_{AC2}/AM_{AC3} \leq 3$, in a very preferred embodiment of the amplitude of the AC-voltage on the toner bearing surface (AC2) and the amplitude of the AC-voltage on the control electrodes (AC3) are such that $0.75 \leq AM_{AC2}/AM_{AC3} \leq 1.33$, most preferably said peak to peak voltages are so that $AM_{AC2}/AM_{AC3} = 1.00$.

[0035] It was found that the frequency of the AC-voltage on the toner bearing surface (f_{AC2}) and the frequency of the AC-voltage on the control electrodes (f_{AC3}) are preferably chosen such that $f_{AC2} = n\ f_{AC3}$, wherein n is an integer, most preferably n = 1. It is, however, possible to use frequencies that do not differ by an integer factor, but then unevenness in the printing is observed, but since in large format printing (e.g., on a billboard or poster) an unevenness that appears, e.g., every 3 lines is merely invisible from the normal viewing distance so that in those cases it is not necessary to control the frequencies that accurately. Thus DEP devices wherein f_{AC2} and f_{AC3} do not differ by an integer factor is still within the scope of this invention.

[0036] In the figures 1 to 4, the printing of intermediate densities is shown by letting toner particles pass the printing aperture from the beginning of the line-time and have it continuously open until the desired optical density is reached and then stopping the toner flux, thus opening the printing aperture for a time equal to a fraction of the line-time (LT). As a matter of course any other placement of that fraction of the line-time within the line-time is within the scope of this invention. The fraction of the line-time for opening the printing aperture can, e.g., be located at any moment of the line-time, it is, e.g., equally well possible to divided the fraction in several sub-fractions and then placing the sub-fractions at random or at pre-selected interval within the line-time.

[0037] Grey levels can then be printed by bringing the control electrode and the toner bearing surface only a fraction of the line time (LT) to an out-of-phase combined AC-field, thus promoting the toner flow for only a fraction of the line time (LT). This time modulation is a preferred embodiment of the present invention. It is possible, for increasing the number of grey levels that can be printed, to have a DC-voltage on the control electrodes deviating from the DC-voltage on the toner bearing surface and/ or to have an AC-voltage on the control electrodes deviating from the AC-voltage on the toner bearing surface. Thus it is possible to choose the strength of the AC-field over the gap between the toner bearing surface and the control electrodes such that, e.g. not D_{max} is formed, but only three quarter of D_{max}, half of D_{max}, a quarter of D_{max}, etc. This is a voltage modulation, by combining a time modulation with a modulation of the strength of the AC-field (voltage modulation), it is possible to print a higher number of density levels, than when using time-modulation alone or using the modulation of the strength of the AC-field alone.

[0038] In figure 5 a DEP device according to the present invention is shown. In this device the electric potentials on the different parts of the device are taken as described above.

[0039] The DEP device shown comprises means for delivering toner particles with a non-magnetic mono component development system (101) comprising non-magnetic toner particles (102), stirred by stirring means (101a), a toner propagating roller (101b) rotating in the direction of arrow D, bringing non-magnetic toner particles on the sleeve (103a) placed around a core (103b) of a toner dispensing part (103). The toner dispensing part with toner particles on it rotates in the direction of arrow C and brings the toner particles past a doctor blade (101c) and a charging part (101d) so that the toner dispensing part carries charged non-magnetic toner particles. The sleeve (103a) of the toner dispensing part is in contact with the CTC (104). The sleeve (103a) and the core (103b), which is driven by a motor (not shown), of the toner dispensing part (103) are construed so that the sleeve has an inner diameter slightly larger than the outer diameter of the core, so that in the contact point between the toner dispensing part (103) and the CTC (104) a slack (115) is formed. By doing so the surface over which the CTC and the toner dispensing part make contact is enlarged, with the beneficial effect that a large amount of toner particles is brought on the CTC by every revolution of the toner dispensing part. In a typical, but not limitative, design of a dispensing part (103), wherein the sleeve has an inner diameter slightly larger than the outer diameter of the core, the sleeve has a thickness of about 150 μm and the a diameter of about 20 mm. The sleeve is preferably made of a conductive and flexible material, e.g., organic polymers, nylon, nickel, organic polymeric materials filled with carbon black, etc. the core, which is used for driving the sleeve is contained in the sleeve and the outer diameter of it is smaller than the inner diameter of the sleeve, so that a slack is formed. The drive roller is also preferably made from conductive material and is connected to a voltage source or ground potential.

[0040] A device for generating a DC-voltage and an AC-voltage is connected to the sleeve of the toner dispensing part and applies a DC-voltage (DC1) and an AC-voltage (AC1) to said sleeve.

[0041] Said toner dispensing roller projects charged toner particles towards a charged toner conveyer (CTC) roller (104) delivering an amount of charged toner particles to the surface of said CTC. A device for generating a DC-voltage and an AC-voltage is connected to the sleeve of said CTC and applies a DC-voltage (DC2) and an AC-voltage with amplitude, AM_{AC2} and a frequency, f_{AC2}, to said sleeve. Said CTC is preferably made of aluminium of other (semi)-conductive materials and can have a conductive, semi-conductive or isolation coating layer, e.g. comprising a TEFLON (trade name) or silicone polymer.

[0042] The device, as shown, further comprises a back electrode (105) connected to a DC-voltage source applying a voltage DC4 to the back electrode. An image receiving substrate (109) is passed by means for moving the substrate (107) in the direction of arrow A between the printhead structure (106) and the back electrode by conveying means (107). The difference between voltage DC4 and voltage DC2 applies a DC-propulsion field wherein toner particles (111) can migrate from the sleeve of the magnetic brush (the toner bearing surface) to the image receiving substrate on the back electrode. The AC-voltage (AC2) on the sleeve of the CTC increases the amount of toner particles entering the propulsion field so that more toner particles per unit of time can migrate towards the image receiving substrate.

[0043] A printhead structure (106), with an insulating material (106c) carrying control electrodes (106a) is interposed in the flow (111) of toner particles. The control electrodes (106a)are connected to a device for applying a DC-voltage (DC3) and a AC-voltage, with amplitude, AM_{AC3}, and frequency , f_{AC3} , the AC-voltage on the control electrodes is out of phase with respect to the AC-voltage on the CTC. By image-wise modulating the electric potential applied to the control electrodes, the of charged toner particles is image-wise modulated in the vicinity of the control electrodes. The voltage applied to the control electrodes can be varied between a value totally blocking the passage of the toner particles, i.e. when the resulting field from DC2, AC2, DC3, AC3, and DC4 is not sufficient for loosening toner particles from said CTC-roller and bringing them in the vicinity of said printhead structure, to a value that lets the toner flow pass totally unimpeded, i.e. when the resulting field from DC2, AC2, DC3 and AC3 and DC4 is sufficient for loosening toner particles from said CTC-roller and bringing them in the vicinity said printhead structure, where the particles enter the propulsion field towards the image receiving substrate.

[0044] The control electrodes in said printhead structure are placed apart from the toner bearing surface, leaving a gap (d) between the control electrodes and the toner bearing surface; a spacer (110) keeps the gap (d) constant during operation of the device.

[0045] In figure 6 a possible implementation of a driving circuit for providing an image-wise modulation to said control electrodes is shown. A high frequency alternating voltage is created via an oscillating crystal (200) which in this example generates a time fluctuating voltage (block signal) with a frequency of 3.0 kHz and an amplitude of e.g. 5V. Said signal is fed to e.g. 3 operational amplifiers (201). Said first amplifier provides and AC/DC-field of AC1/DC1 to the sleeve of the magnetic brush. Said second amplifier is followed by a phase inverter (202) and delivers an AC/DC-field of AC2/DC2 to the sleeve of the CTC. Said third amplifier delivers an AC signal to the banking input line of control IC (203). Said control IC (203), e.g. SUPERTEX HV507 (trade name), also has a high voltage input signal (300 V) and a low voltage input of image data. The output lines of said IC (203) deliver an AC/DC field of AC3/DC3, said field being between 90° and 270° out of phase compared to the field applied to said CTC-sleeve, to the control electrodes (106a) surrounding the apertures (107).

[0046] In this figure the voltage AC1, AC2 and AC3 originate from a single oscillator. It is possible to operate a DEP device according to this invention with three different oscillators one for each of the voltages AC1, AC2 and AC3. Since in a very preferred embodiment of the invention, the amplitude of the AC-voltage on the toner bearing surface, AM_{AC2}, and the amplitude of the AC-voltage on the control electrodes, AM_{AC3}, are such that $AM_{AC2}/AM_{AC3} = 1$ and the frequency of the AC-voltage on the toner bearing surface (f_{AC2}) and the frequency of the AC-voltage on the control electrodes (f_{AC3}) are preferably chosen such that $f_{AC2} = n\ f_{AC3}$, wherein n = 1, it is preferred to have a single oscillator for generating voltage AC2 and AC3.

[0047] The device comprises further means (108) for fixing the toner particles to the image receiving substrate.

[0048] In figure 5 the toner bearing surface, TS, is the surface of the sleeve of a charged toner conveyer (CTC). However, a DEP device according to this invention can also function when the charged toner particles are directly extracted from a magnetic brush that carries either magnetic mono-component developer or a two component developer, with non-magnetic toner particles and magnetic carrier particles. It can also function when the charged toner particles are directly extracted from the toner dispensing part of a non-magnetic mono-component development system. The device according to this invention can be operated with any device known in the art of DEP having a surface carrying charged toner particles for delivering them to the image receiving member.

[0049] The control electrodes can be coupled to a means for generating an AC-field on said control electrodes and a means for selectively switching said AC-field to the on and off condition in accordance with image data. Typical DEP devices that can be adapted for producing a device according to this invention are disclosed in, e.g., **EP-A-795 802, EP-A-780 740, EP-A-740 224, EP-A-731 394, EP-A-712 055, US-A-5 606 402, US-A-5 523 777, GB-A-2 108 432, US-A-4 743 926**, etc..

[0050] The insulating material, used for producing printhead structure, useful in a DEP device according to the present invention, can be glass, ceramic, plastic, etc. Preferably said insulating material is a plastic material, and can be a polyimide, a polyester (e.g. polyethylelene terephthalate, polyethylene naphthalate, etc.), polyolefines, an epoxy resin, an organosilicon resin, rubber, etc.

[0051] The selection of an insulating material for the production of a printhead structure useful in a DEP device according to the present invention, is governed by the elasticity modulus of the insulating material. Insulating material, useful in the present invention, has a elasticity modulus between 0.1 and 10 GPa, both limits included, preferably between 2 and 8 GPa and most preferably between 4 and 6 Gpa. The insulating material has a thickness between 12 and 1000 µm, preferably between 25 and 200 µm.

[0052] The back electrode (105) of a DEP device according to this invention, can also be made to co-operate with the printhead structure, said back electrode being constructed from different styli or wires that are galvanically isolated and connected to a voltage source as disclosed in e.g. **US-A- 4, 568 ,955** and **US-A-4, 733, 256** . The back electrode, co-operating with the printhead structure, can also comprise one or more flexible PCB's (Printed Circuit Board).

[0053] A DEP device according to the present invention can also be operated without back electrode. Devices wherein DEP is practised without back electrode are described in EP-A-823 676 and EP-A-952 498. In both cases the substrate whereon the printing proceeds is an insulating substrate and a conductive layer on the substrate is couple to a voltage source and is thus used as "back electrode".

[0054] The present invention incorporates the operation of a DEP device according to the present invention in a method for direct electrostatic printing comprising the steps of :

- providing charged toner particles on a surface of a means for delivering toner particles, forming a toner bearing surface,
- coupling said toner bearing surface an AC-voltage source for applying an AC-voltage, AC2, having an amplitude, AM_{AC2}, and a frequency, f_{AC2}, to said surface,
- creating an electric potential difference between said surface and an image receiving substrate for migrating charged toner particles from said surface to said image receiving substrate from,
- placing a printhead structure, with printing apertures and control electrodes in said flow of toner particles, leaving a gap (d) between said toner bearing surface and said control electrodes,
- coupling said control electrodes to an AC-voltage source for applying an AC-voltage, AC3, having an amplitude, AM_{AC3}, and a frequency, f_{AC3} to said electrodes,
- arranging said AC-voltage sources so that $1/3 \leq AM_{AC2}/AM_{AC3} \leq 3$ and that said AC-voltage, AC3, is between 90° and 270° out of phase with respect to said AC-voltage, AC2,
- selectively switching said AC-voltage, AC3, in accordance with image data, to a value for opening said printing apertures and to a value blocking said printing apertures, for image-wise depositing toner particles on said image receiving substrate.

[0055] A DEP device making use of the above mentioned marking toner particles can be addressed in a way that enables it to give black and white. It can thus be operated in a "binary way", useful for black and white text and graphics and useful for classical bi-level halftoning to render continuous tone images.

[0056] A DEP device according to the present invention is especially suited for rendering an image with a plurality of grey levels. Grey level printing can be controlled by either an amplitude modulation of the AC and/or DC-voltage applied on the control electrodes 106a and/or by a time modulation of said AC an/or DC-voltage. By changing the duty cycle of the time modulation at a specific frequency, it is possible to print accurately fine differences in grey levels. It is also possible to control the grey level printing by a combination of an amplitude modulation and a time modulation of the voltages, applied on the control electrode.

[0057] The combination of a high spatial resolution and of the multiple grey level capabilities typical for DEP, opens the way for multilevel half-toning techniques, such as e.g. described in EP-A-634 862 with title "Screening method for a rendering device having restricted density resolution". This enables the DEP device, according to the present invention, to render high quality images.

EXAMPLES

The printhead structure.

[0058] A printhead structure (106) was made from a polyimide film of 50 µm thickness (106c), double sided coated with a 5 µm thick copper film. The printhead structure (106) had two rows of printing apertures. On both sides of the printhead structure, a rectangular shaped control electrode (106a) was arranged around each aperture. Thus each aperture has a pair of control electrodes that were switched together. Each of said pairs control electrodes was connected over 2 MΩ resistors to a HV 507 (trade name) high voltage switching IC, commercially available through Supertex, USA, that was powered from a high voltage power amplifier. The printing apertures were square shaped with dimensions, of 100 by 100 µm. Two of said apertures, separated by a free zone of 50 µm, were combined in a single control electrode. Said two rows of printing apertures were staggered to obtain a printing resolution of 100 dpi. The width of the connecting lines was 75 µm. Said printhead structure was fabricated in the following way. First of all the control electrode pattern on both sides of the polyimide was etched by conventional copper etching techniques. The apertures were made by a step and repeat focused excimer laser making use of the control electrode patterns as focusing aid. After excimer burning the printhead structure was cleaned by a short isotropic plasma etching cleaning. Finally a thin coating of PLASTIK70, commercially available from Kontakt Chemie, was applied over the control electrode side of said printhead structure.

COMPARATIVE PRINTING EXAMPLE 1 (CPE1)

PRIOR ART situation: AC-voltage on control electrodes, DC on toner bearing member. (See figure 1 of this application)

[0059] As toner delivery means a charged toner conveyer roller fed from a non-magnetic mono-component development system, commercially available from Lexmark (CYAN TONER CARTRIDGE 1361752 for the LEXMARK OPTRA SC1275 (trade name) printer) was used. The commercial toner was for the experiment taken out of the cartridge and mixed with 0.8 % by weight of hydrophobic TiO_2 (T805 available from Degussa Germany). The this new mixture was introduced in the cartridge again and used in the printing.

[0060] The front roller i.e. the "toner dispensing part" of said non-magnetic mono-component development system was in direct contact over the charged toner particles with said CTC-roller. The CTC roller was a cylinder with a sleeve made of aluminium, coated with TEFLON (trade name of Du Pont, Wilmington, USA) with a surface roughness of 2.2 mm (Ra-value) and a diameter of 30 mm. The roller of the non-magnetic mono-component development system was rotated at a linear surface speed of 7.5 m/min, the CTC was rotated at a linear surface speed of 5 m/min.

[0061] The printhead structure, mounted in a PVC-frame, was bent with frictional contact over the surface of the roller of the toner delivery means. A 90 μm thick polyurethane coating was used as self-regulating spacer means (110), so that the distance between the surface of the CTC-roller and front side of the printhead structure remained constant at 90 μm.

[0062] A back electrode was present behind the paper whereon the printing proceeded, the distance between the back electrode (105) and the back side of the printhead structure (i.e. control electrodes (106a)) was set to 1000 μm and the paper travelled at 5 m/min. A DC-voltage of +1250 V was applied to said back electrode.

[0063] A crystal oscillator providing an alternating block voltage of 5 V and 3.0 kHz was used as input signal for 3 operational amplifiers. A first operational amplifier created an AC/DC-potential of 530 V (peak to peak) with + 130 V DC-offset (AC1/DC1) which was applied to the sleeve, the doctor blade, and the conductive strip of the Lexmark Toner Cartridge. The second amplifier was not used in this experiment. The third operational amplifier was used to deliver an AC-voltage (3.0 kHz, 5 V peak to peak) to the blanking input signal of the Supertex HV507 high voltage power IC. Said control IC had a grounded earth level and +300 V high voltage input, and as a result the output signals provided a switching AC/DC-potential of 0 to +300 V (i.e. AC3 had a peak to peak voltage (amplitude) of 300 V with + 150 V DC-offset) to the control electrodes. The output AC3/DC3-level was controlled from the image data that are also fed to the control IC. So, during the ON-time an alternating voltage (AC3/DC3) is present upon the control electrodes, during OFF-time, the control electrodes are grounded. The surface of the CTC bearing charged toner particles is grounded. When the control electrode are grounded during OFF-time, AC-field is present over the gap between CTC and printhead structure, when AC-voltage, AC3, with DC-bias, DC3, is applied to the control electrodes during on time, an AC-field is present over the gap between CTC and printhead structure and there is enough toner motion between the surface of the CTC to bring toner particles in the vicinity of the printing apertures where these particles enter the propulsion field towards the image receiving member.

[0064] Printing was performed during 1 hour. After one hour no significant toner adhesion was observed upon said printhead structure. From the final printouts it could be observed that even after the periods of D_{min}-printing nozzle blocking did not occur and changing the image info to D_{max} resulted in a sharp transition. The D_{max} was however very low and was only 0.18.

PRINTING EXAMPLE 1 (PE1)

[0065] The same experiment as described in comparative printing example 1 was performed except that a crystal oscillator providing an alternating block voltage of 5 V and 3.0 kHz was used as input signal for 3 operational amplifiers. In this experiment a second operational amplifier and phase inverter was used to apply an AC-voltage (AC2) with a peak to peak voltage of 400V and with a DC-offset of + 220 V, said AC-component being essentially 180° out of phase if compared with the AC-component that was applied to the control electrodes. This AC/DC-potential (AC2/DC2) was applied to the sleeve of the CTC-roller. So, during the ON-time an alternating voltage (AC3/DC3) is present upon the control electrodes while an 180° out of phase alternating voltage (AC2/DC2) with the same frequency is available upon the sleeve of the CTC-roller. The AC-field, in the gap between the printing apertures and the surface of the CTC, created by the AC-voltage, AC2, is enhanced by placing an out-of-phase AC-field upon the control electrodes, the net resulting AC-field is increased to a level where a large amount of toner particles are removed from the surface of the CTC and brought in the vicinity of the printing apertures from where they enter the propulsion filed towards the image receiving substrate. During OFF-time, said alternating voltage (AC2/DC2) remains present upon the sleeve of the CTC-roller, but on the control electrodes only a DC-voltage of 0 V is present (i.e. the control electrodes are grounded). As a consequence the AC-field present in the gap between the printing apertures and the surface of the CTC not strong enough for toner particles to move through the printing apertures.

[0066] Printing was performed during 1 hour. After one hour no significant toner adhesion was observed upon said printhead structure. From the final printouts it could be observed that even after the periods of D_{min}-printing nozzle blocking did not occur and changing the image info to D_{max} resulted in a sharp transition. Prolonged printing periods of Dmin-density kept the image density fog at zero level, while afterwards the D_{max} density remained at a constant 1.25.

PRINTING EXAMPLE 2

[0067] In this experiment a non-magnetic mono-component development system, commercially available from Apple (Cyan Toner Cartridge M3757 G/A for the APPLE COLOR LASER WRITER 12/600 PS (trade name) printer) was used to jump toner particles directly towards the printhead structure. The front roller of this toner delivery means was rotated at a linear speed of 10 m/min.

[0068] The printhead structure used in this experiment was equal to the one used in comparative printing example 1 and printing example 1, but instead of having a pair of control electrodes around each aperture it carried a shield electrode common to every aperture on one side, said shield electrode leaving an open zone of 1620 µm. It was mounted in a PVC-frame, was bent with frictional contact over the surface of the roller of the toner delivery means. A 70 µm thick polyurethane coating was used as self-regulating spacer means (110), so that the distance between the surface of the CTC-roller and the shield electrode side of the printhead structure remained constant at 70 µm.

[0069] A back electrode was present behind the paper whereon the printing proceeded, the distance between the back electrode (105) and the back side of the printhead structure (i.e. control electrodes (106a)) was set to 500 µm and the paper travelled at 5 m/min. To the back electrode a DC-voltage of + 400 V was applied. The shield electrode was grounded.

[0070] A crystal oscillator providing an alternating block voltage of 5 V and 2.8 kHz was used as input signal for 2 operational amplifiers. A first operational amplifier and phase inverter created a first AC/DC-potential of 430 V (peak to peak) with + 50 V DC-offset and was applied to the toner bearing roller of the Apple Toner Cartridge (AC2/DC2). A second operational amplifier was used to deliver an AC-component (2.8 kHz, said AC-component being essentially 180° out of phase if compared with the AC-component that was applied to the sleeve of the toner bearing roller) to the blanking input signal of the Supertex HV507 high voltage power IC. Said control IC had a grounded earth level and +300 V high voltage input, and as a result the output signals provided a switching AC/DC-potential of 0 to +300 V (AC3/DC3 of 300 V (peak to peak) with + 150 V DC-offset) to the control electrodes, said switching voltage being essentially 180° out of phase compared to the AC-component applied to the sleeve of the toner bearing roller, and said output AC3/DC3-level being controlled from the image data that are also fed to the control IC. So, during the ON-time an alternating voltage (AC3/DC3) is present upon the control electrodes while an 180° out of phase alternating voltage (AC2/DC2) with the same frequency is available upon the sleeve of the toner bearing roller. During OFF-time, said alternating voltage (AC2/DC2) remains present upon the sleeve of the toner bearing roller, but on the control electrodes a DC-voltage of 0 V is present, i.e. the control electrodes are grounded. As a consequence the AC-field present upon the sleeve of the toner bearing roller is not strong enough for toner particles to move through the printing apertures, but when this AC field is enhanced by placing an out-of-phase AC-field upon the control electrodes, the net resulting AC-field is increased to a level where toner motion through said printing apertures does take place.

[0071] Printing was performed during 1 hour. After one hour no significant toner adhesion was observed upon said printhead structure. From the final printouts it could be observed that even after the periods of D_{min}-printing nozzle blocking did not occur and changing the image info to D_{max} resulted in a sharp transition. Prolonged printing periods of D_{min}-density kept the image density fog at zero level, while afterwards the D_{max} density remained constant at 1.16.

PRINTING EXAMPLE 4 (PE4)

[0072] The same experiment as described in printing example 4 was performed except that a separate crystal oscillator was used with separate amplifier to create an block AC-voltage (AC2/DC2) with a frequency of about 2.8 kHz and an amplitude of 430 V (peak to peak) with +50 V DC-offset, but with no synchronisation between said two AC-voltages. The maximum image density dropped by 50% compared to the one reached in printing example 3, and density fluctuations having a lower frequency also occurred in the printouts. So, it must be evident that keeping half of the applied AC-field upon the control electrodes, and half of the applied AC-field on the toner bearing roller, but without any synchronisation, considerably reduces the maximum print density and print quality. Although the switching of the printing apertures by modulating the AC-voltage on the control electrodes was possible, the banding was severe when the two AC-voltages were totally un-synchronised.

[0073] It is thus clear that a DEP device wherein printing is realised by applying a first AC-voltage upon a surface bearing charged toner particles with an amplitude that is not sufficient for toner particles to pass through the printing apertures, and enhancing said AC-field present between the toner bearing surface and the printhead structure, by applying a second AC-voltage (which is out of phase with respect to the first AC-voltage) upon the control electrodes, could combine the beneficial effects of the device disclosed in EP-A-911 706 with fast printing at high density.

Claims

1. A device for direct electrostatic printing comprising

- a means for delivering charged toner particles, said means having a toner bearing surface coupled to a means for applying an AC-voltage, AC2, with an amplitude, AM_{AC2}, and a frequency, f_{AC2},
- a means for making charged toner particles migrate away from said surface to an image receiving substrate, placed opposite to said surface,
- a printhead structure, having printing apertures and control electrodes associated therewith, placed between said toner bearing surface and said image receiving substrate, leaving a gap (d) between said toner bearing surface and said control electrodes,

characterised in that

- said control electrodes are coupled to a second means for applying an AC-voltage, AC3, being between 90° and 270° out of phase with respect to said AC-voltage, AC2, and having an amplitude, AM_{AC3}, and a frequency, f_{AC3}, wherein said amplitude, AM_{AC3}, being chosen so that $1/3 \leq AM_{AC2}/AM_{AC3} \leq 3$, and in that
- a means is placed between said control electrodes and said means for generating said AC-voltage, AC3, for selectively switching said AC-voltage, AC3, in accordance with image data to a value stopping said toner particles from passing said printing apertures and a value allowing said toner particles to pass said printing apertures.

2. A device according to claim 1, wherein said second amplitude being chosen so that $AM_{AC2}/AM_{AC3} = 1.00$.

3. A device according to claim 1 or 2, wherein said second AC-voltage is 180° out of phase with respect to said first AC-voltage.

4. A device according to any of claims 1 to 3, wherein said frequency of the AC-voltage on the toner bearing surface (f_{AC2}) and said frequency of the AC-voltage on the control electrodes (f_{AC3}) are chosen such that $f_{AC2} = n\, f_{AC3}$, wherein n is an integer.

5. A device according to claim 4, wherein n = 1.

6. A device according to any of the preceding claims wherein said first and said second AC voltage originate from a single oscillator.

7. A device according to any of the preceding claims, wherein said first and said second AC-voltage are square-waves.

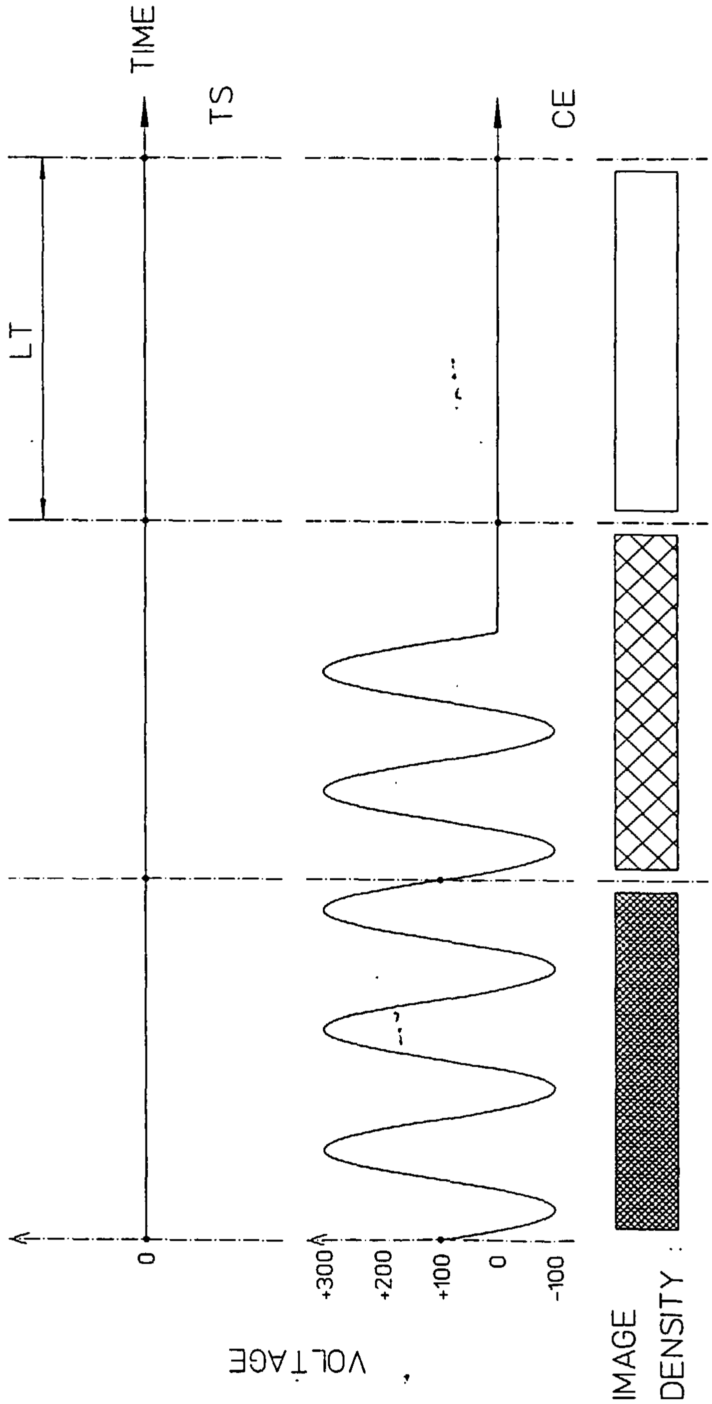
8. A method for direct electrostatic printing comprising the steps of :

- providing charged toner particles on a surface of a means for delivering toner particles, forming a toner bearing surface,
- coupling said toner bearing surface an AC-voltage source for applying an AC-voltage, AC2, having an amplitude, AM_{AC2}, and a frequency, f_{AC2}, to said surface,
- creating an electric potential difference between said surface and an image receiving substrate for migrating charged toner particles from said surface to said image receiving substrate from,
- placing a printhead structure, with printing apertures and control electrodes in said flow of toner particles, leaving a gap (d) between said toner bearing surface and said control electrodes,
- coupling said control electrodes to an AC-voltage source for applying an AC-voltage, AC3, having an amplitude, AM_{AC3}, and a frequency, f_{AC3} to said electrodes,
- arranging said AC-voltage sources so that $1/3 \leq AM_{AC2}/AM_{AC3} \leq 3$ and that said AC-voltage, AC3, is between 90° and 270° out of phase with respect to said AC-voltage, AC2,
- selectively switching said AC-voltage, AC3, in accordance with image data, to a value for opening said printing apertures and to a value blocking said printing apertures, for image-wise depositing toner particles on said image receiving substrate.

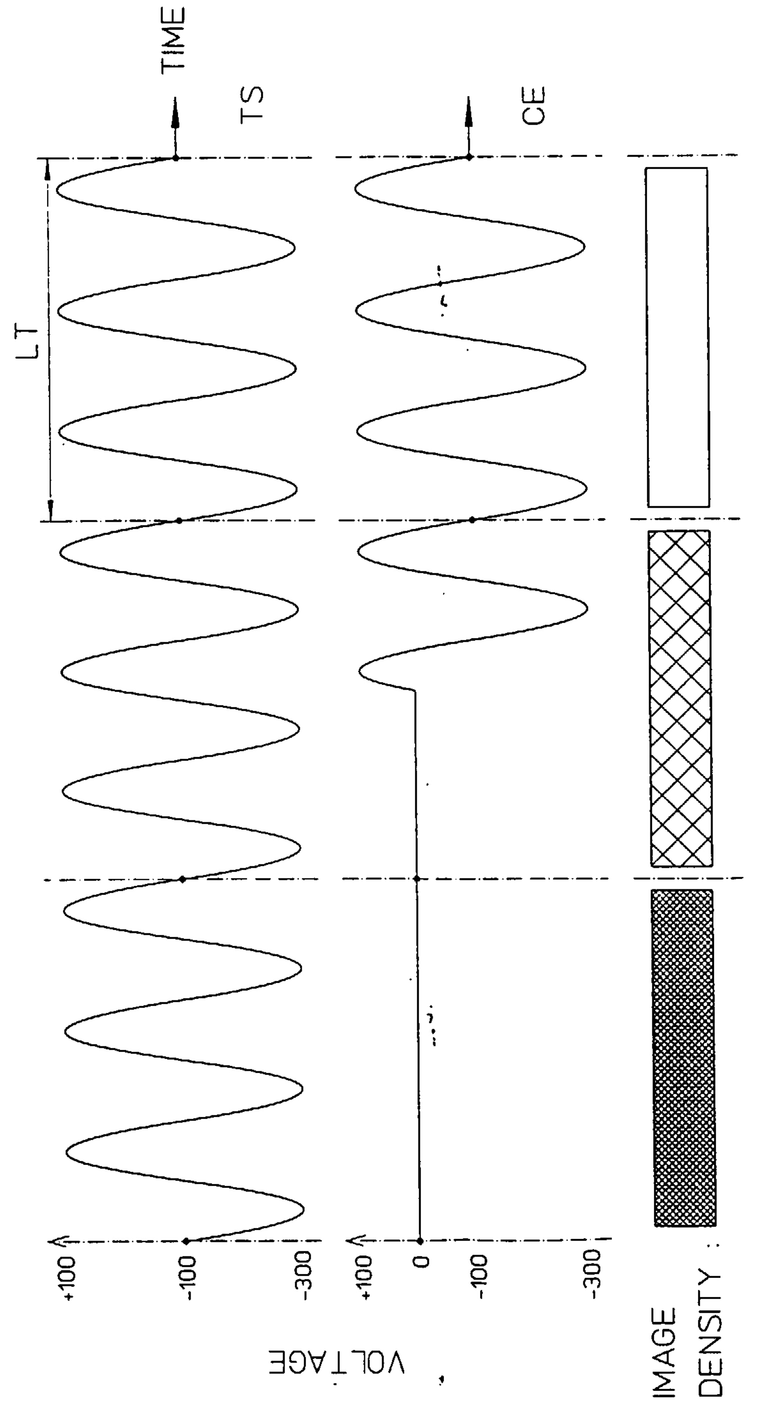
9. A method according to claim 7, wherein in said step of coupling said control electrodes to a second AC-voltage source, said second AC-voltage source is arranged so that AC2/AC3 = 1 and that said second AC-voltage is 180° out of phase with respect to said first voltage source.

10. A method according to claim 7 or 8, wherein in said step of coupling said control electrodes to a second AC-voltage source, said second AC-voltage source is arranged so that $f_{AC2} = n\, f_{AC3}$, wherein n is an integer.

11. A method according to claim 9, wherein n = 1.



PRIOR ART
Fig 1



PRIOR ART
Fig 2

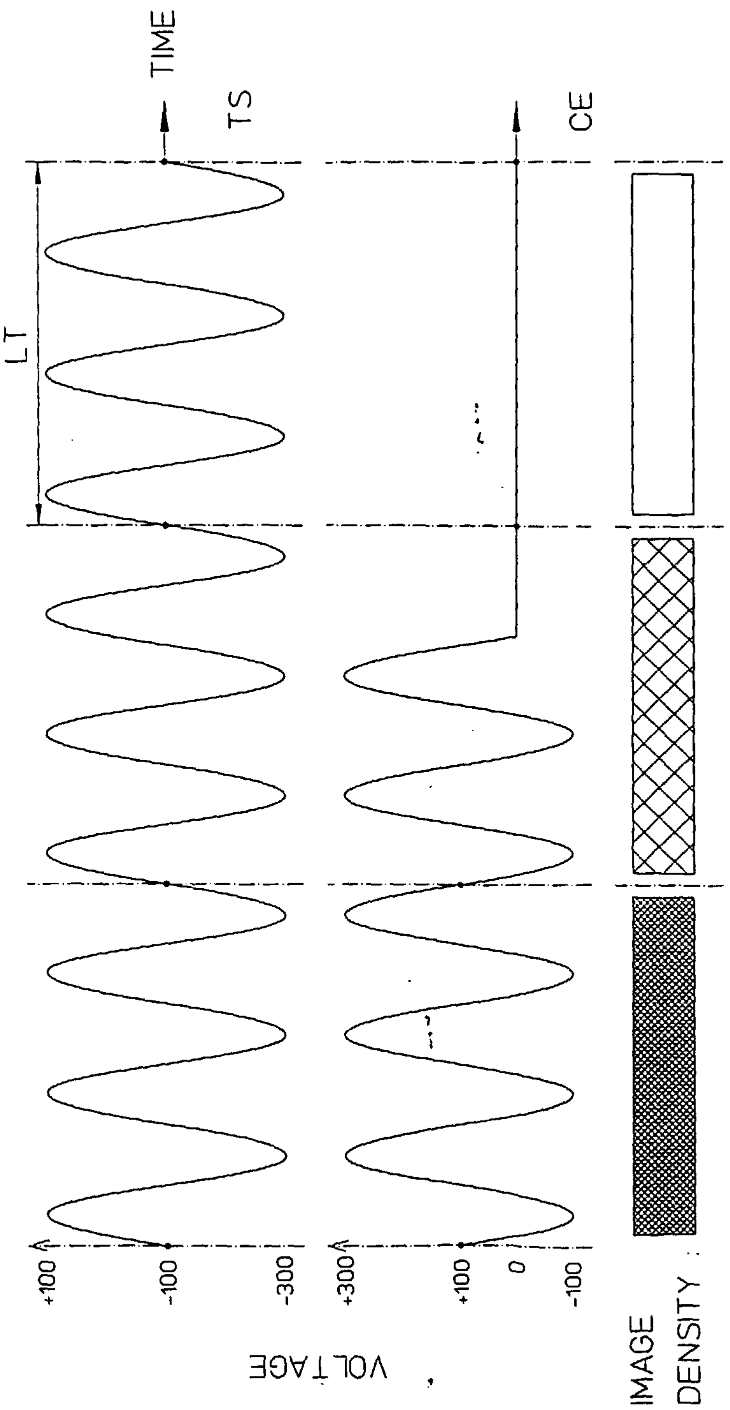


Fig 3

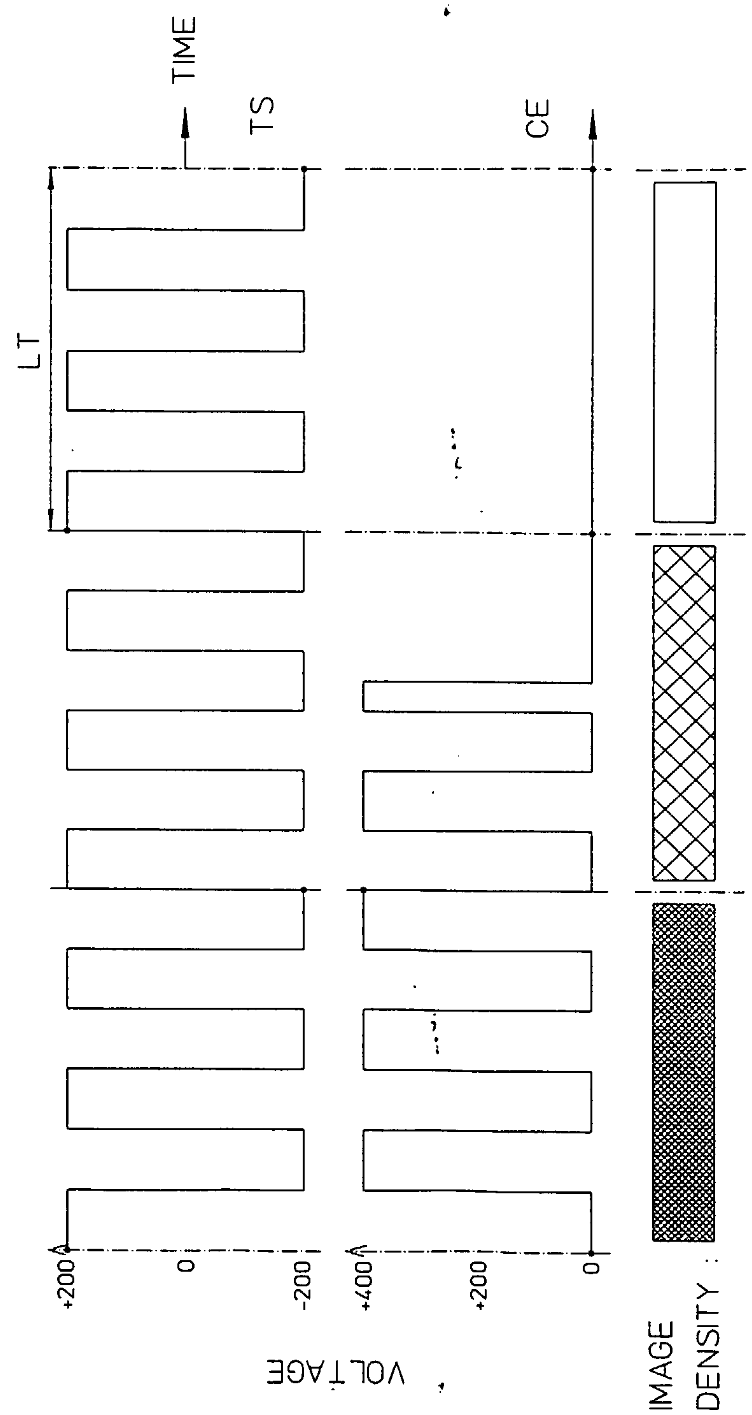
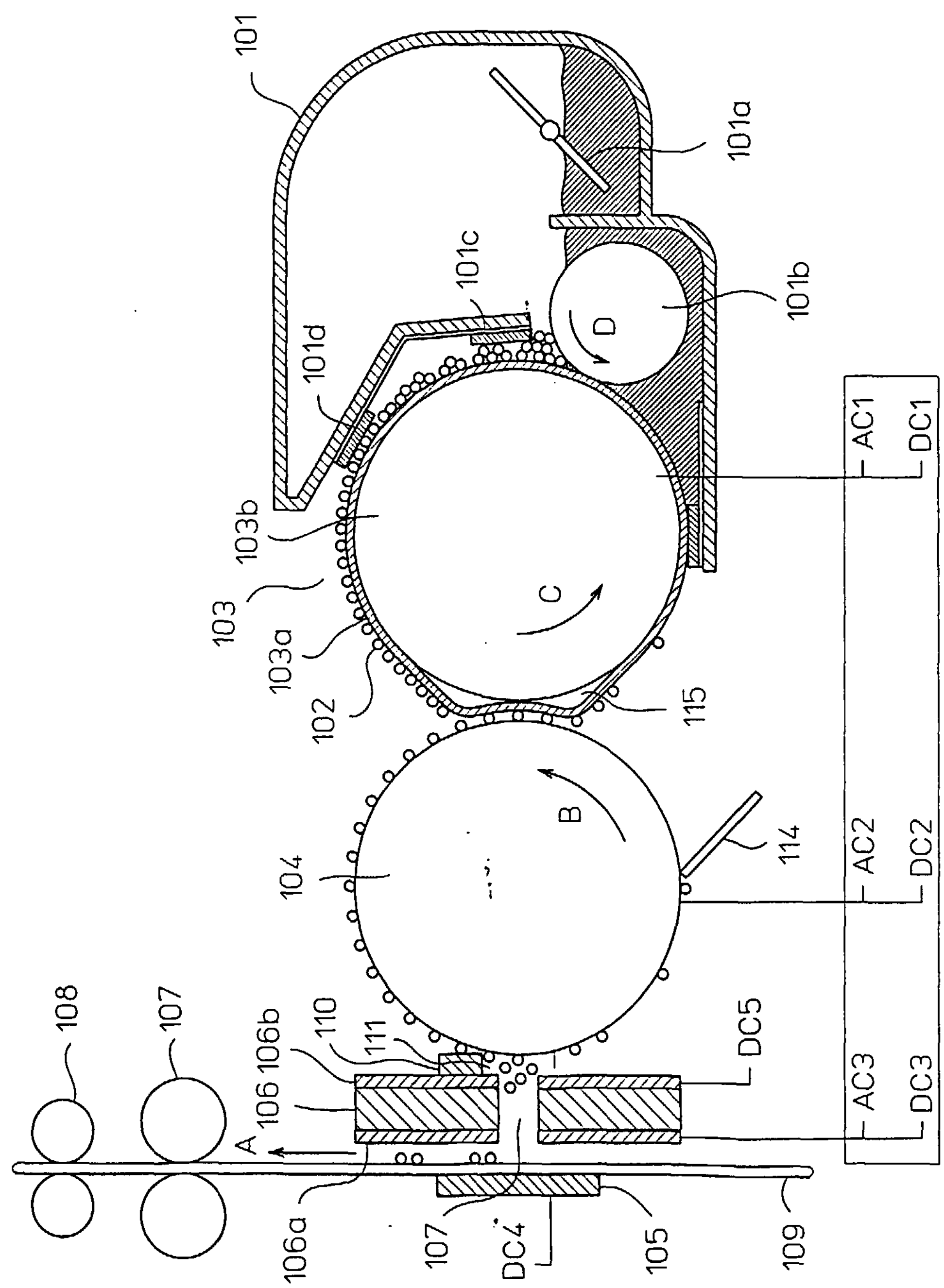


Fig 4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101c
101d
D
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C
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104
B
114
AC1
DC1
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DC5
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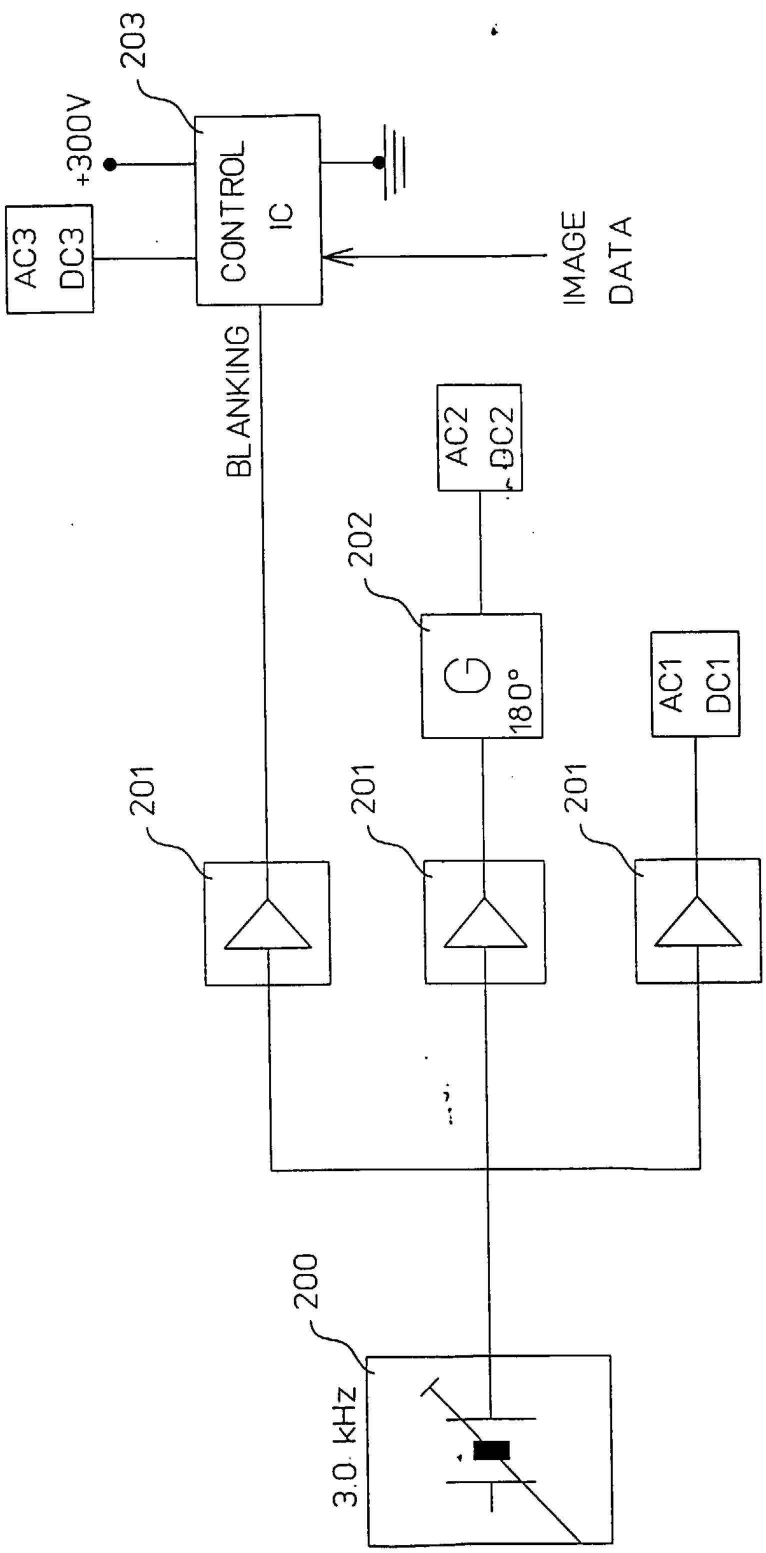
106a
107
DC4
105
109

Fig. 5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+300V
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DC3
CONTROL
IC
IMAGE
DATA
BLANKING
AC2
DC2
202
G
180°
AC1
DC1
201
201
201
200
3.0 kHz

Fig 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 20 3305

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	EP 0 911 706 A (AGFA GEVAERT NV) 28 April 1999 (1999-04-28) * column 9, line 20 - column 12, line 5 * ---	1,8	B41J2/415
D,A	US 5 095 322 A (FLETCHER GERALD M) 10 March 1992 (1992-03-10) * column 4, line 52 - column 6, line 28; figure * -----	1,8	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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 March 2000	De Groot, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 20 3305

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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21-03-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0911706 A	28-04-1999	JP 11198428 A	27-07-1999
US 5095322 A	10-03-1992	JP 4290758 A	15-10-1992

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82