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"PRINTING APPARATUS"

This invention relates to printing apparatus.

Hard copy colour printing apparatus has recently been proposed. Such colour printing apparatus mainly utilises an ink jet printing head or a thermal transfer printing head. In both methods, the darkness or intensity of the printed image is determined by a quasi-area modulation such as a dither matrix, for obtaining a full-colour image. This is because the area of one dot is modulated stably only due to the presence of a colour picture element. Thus, in order to maintain a predetermined resolution of the picture element either a recording head having an extremely high density of printing elements, or high density recording is required. For example, when a (4 x 4) matrix is used to represent 16 gray scales at 5 dot/mm density of the picture element, 20 dot/mm of resolution is necessary in a line head, whilst in a single head, the speed is reduced to one sixteenth of that of the case when gray scale is not represented. Known thermal transfer printing heads are either highly expensive or their speed is extremely slow.

U.S. Patent Specification No. 4 350 449 discloses a thermal transfer printing apparatus which is shown in Figure 24. An ink sheet consists of a resistive layer 251, an electrically conductive layer 252 and ink layer 254 on which there is a record medium 255. A printing electrode 256 and a return electrode 257 are in contact with the resistive layer 251

and a voltage is applied therebetween. As current flows through the resistive layer 251 and the conductive layer 252, heat is generated in a portion 251a of the resistive layer 251. This heat causes melting of thermally transferrable material in a contiguous portion 254a of the ink layer 254 and thus a printed image is formed on the record medium 255. The current flowing through the resistive layer 251 concentrates in the portion just under the printing electrode 256 since current flows into the conductive layer 252 whose resistance is lower than that of the resistive layer 251. As a result a dot having the same area as the printing electrode 256 is formed on the record medium. Although this type of printing apparatus has the advantage of high speed, it is necessary to form a matrix in the same manner as with a thermal transfer printing head for gray scale. Consequently, in spite of the advantage of high speed, this known printing apparatus is very expensive.

According to one particular aspect of the present invention there is provided a printing apparatus comprising: an ink sheet member including at least a resistive layer and an ink layer; a head including a first electrode and at least a second electrode, said first and second electrodes being, in operation,

in contact with said resistive layer of the ink sheet member and connected to a drive circuit for causing current to flow through said ink sheet member; and a control circuit including a gray scale signal generating means and a pulse width setting means
5 for modulating the pulse width of the voltage applied to said electrodes in response to said gray scale signal, said head and said ink sheet member being so arranged that the current flowing through said ink sheet member passes through said resistive layer.

10 According to a further non-restrictive aspect of the present invention there is provided a printing apparatus comprising: an ink sheet member including at least a resistive layer and an ink layer, said ink layer being disposed to be opposed to record medium and having a plurality of different coloured ink
15 constituents; a head including a first electrode and at least a second electrode, said first and second electrodes being, in operation, in contact with said resistive layer of the ink sheet member and connected to a driving circuit for causing current to flow in the ink sheet material; and a control circuit
20 including a colour signal generating means for generating three colour signals according to three primary colours, and a pulse width setting means for modulating the pulse width of the voltage applied to said electrodes in response to said three colour signals, said head and said ink sheet member being
25 arranged so that the current flowing in the ink sheet member

flows through the resistive layer to transfer the coloured ink constituents of said ink layer onto the record medium in response to said three colour signals.

5 An ink sheet member may have an insulating support layer between said resistive layer and said ink layer. Alternatively said ink sheet member may consist solely of said resistive layer and said ink layer. A still further possibility is that said ink sheet member comprises said resistive layer and said ink layer which are formed as a single layer.

10 In the preferred embodiment a plurality of said first electrodes are arranged in a line between a plurality of pairs of said opposed second electrodes, the control circuit being arranged to drive said first and second electrodes by time-sharing.

15 In one embodiment the first electrode is of a pin shape and each second electrode is planar. In another embodiment the first and second electrodes are of a pin shape.

Said ink sheet member may have a plurality of transverse bands of ink of different colour arranged thereon.

20 A printing apparatus according to the present invention may comprise detection means for detecting the relative position of said ink sheet member and said head to transfer different colour ink from the ink layer to the portion of the record medium beneath the head.

25 The ink layer may comprise yellow, magenta and cyan colour constituents or alternatively yellow, magenta, cyan and black

colour constituents.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:-

Figure 1 illustrates schemmatically the fundamental
5 construction of a printing apparatus according to the present invention;

Figure 2 consists of Figure 2(a) which illustrates potential distribution in a conductive layer of a thermal printing sheet used with a printing apparatus according to the present
10 invention, and Figure 2(b) which illustrates the corresponding temperature distribution;

Figure 3 shows graphically the relationship between printing energy and optical density of a printed image;

Figure 4 is a block diagram of a pulse width modulator
15 of a printing apparatus according to the present invention;

Figure 5 consists of Figure 5(a) which shows the pulse width modulator of Figure 4 in greater detail and Figure 5(b) which shows by way of a time chart the operation thereof;

Figure 6, consisting of Figure 6(a) and 6(b) illustrate
20 schemmatically a recording head of a printing apparatus according to the present invention;

Figure 7, consisting of Figure 7(a) and 7(b), illustrates the fundamental principle of driving a head of a printing apparatus according to the present invention dynamically;

25 Figure 8 illustrates an equipotential surface in a

conductive layer of a thermal printing sheet used with a printing apparatus according to the present invention;

Figure 9 illustrates schemmatically a conventional multi-stylus static electric printer;

5 Figure 10 illustrates the potential distribution created in a conductive layer of a thermal printing sheet by the conventional multi-stylus static electric printer of Figure 9;

Figure 11 illustrates by means of a timing chart dynamic driving of a printing apparatus according to the present
10 invention;

Figure 12 is a block diagram of an embodiment of a printing apparatus according to the present invention;

Figure 13 is a block diagram of a driving circuit of a printing apparatus according to the present invention;

15 Figure 14 is a timing chart showing the operation of the driving circuit of Figure 13;

Figure 15 is a circuit diagram of a selecting gate of the driving circuit of Figure 13;

Figure 16 is a circuit diagram of a driver of the
20 driving circuit of Figure 13;

Figure 17 is a circuit diagram of a further driver of the driving circuit of Figure 13;

Figure 18 is a block diagram of a picture signal generating circuit for a printing apparatus according to the
25 present invention;

Figure 19 illustrates schematically a full-colour printing apparatus according to the present invention;

Figure 20 shows a thermal printing sheet for the printing apparatus of Figure 19;

5 Figure 21 consists of Figure 21(a) which illustrates schematically another embodiment of a printing apparatus according to the present invention and Figure 21(b) which is an equivalent circuit diagram thereof;

10 Figure 22 illustrates a printing head of the pin type of another embodiment of a printing apparatus according to the present invention;

Figure 23 shows thermal printing sheets for use with the printing head of Figure 22; and

15 Figure 24 illustrates schematically a thermal transfer printing apparatus disclosed in U.S. Patent Specification No. 4,350,449.

Throughout the drawings like parts have been designated by the same reference numerals.

20 Figures 1 and 2 illustrate the fundamental principle of a printing apparatus according to the present invention. A thermal printing sheet 1 includes a resistive layer 2, a support layer 3 and heat-fusible ink layer 4. The support layer 3 is also electrically insulating and thermally conductive.

25 When a voltage is applied to a recording electrode 5 by a signal voltage generating circuit 7, current flow into

common electrodes 6 through the resistive layer 2. If the area of the common electrodes 6 is much larger than the contact area of the recording electrode 5 and the resistive layer 2, heat is generated just under the recording electrode 5. The heat
5 generated melts the heat-fusible ink in the ink layer 4 by transmission through the support layer 3. As a result, a melted portion 10 of the heat-fusible ink is transferred onto a record medium 8, and thereby printing is effected.

On close examination of the potential distribution in the
10 resistive layer 2 there is seen to be a very sharp potential curve in the area around the recording electrode 5 as illustrated in Figure 2(a). Thus, the thermal distribution in the thermal sheet 1 which is energised has a central peak as seen in Figure 2(b). A dotted line represents the condition where the
15 supplied energy is larger than in the case represented by a solid line. In Figure 2(b) the vertical axis represents temperature and the horizontal axis represents position and corresponds to Figure 2(a). If the melting point of the heat-fusible ink is T_s , the area of thermal distribution cut by a
20 line representing the temperature T_s changes according to the supplied energy. Namely, the area of the potential distribution where solid ink can be melted varies in dependence upon the supplied energy, and thereby the area of printed dots can be modulated. Figure 3 shows the relationship between printing
25 energy (E) and optical density (OD) of a printed image. As

the area of each dot can be modulated, there is no need to construct dots in a matrix, which results in advantages such as reduction in cost and increase in speed.

Figures 4 and 5 illustrate a pulse width modulator of a printing apparatus according to the present invention. Image data 21 of n bits per picture element is delivered from an image signal generator 10 on receipt of a request signal 23 from a control signal generating circuit 14 and is stored in a memory 12 through a tristate gate 11. When 1 word is "n" bits, l words data is read out again from the memory 12, converted by a gamma converting table 13 to signal data 22 of m bits which is suitable for a printed image, and then transmitted to a (m x 1) bit shift register 15 controlled by a signal 26 from the control signal generator 14. It may be possible to make the value m equal to n, but the value of m is dependent on the capability of transferring gray scales. In the construction shown in Figure 4 the size of the memory 12 can be economised by making n greater than m.

"l" words of a m bit data transmitted from a shift register 15 are latched by a counter 16 in response to a signal 27. A carry signal 30 corresponding to each data is generated in "l" counters 16 in response to a clock signal 28 when each counter is "m" bits. "l" bit of a flip-flop 17 is respectively set or reset in response to a set signal 29 or the carry signal 30 to obtain l pulse width signals 31 with every data. Meanwhile, the next l words data is transmitted to the shift register 15.

Figure 5(b) is a timing chart associated with operation of the circuit of Figure 5(a). Reference numeral 24 represents address signals and control signals for the memory 12 and reference numeral 25 represents those for the gamma converting table 13.

Figure 6 is a schematic view of a recording head of a printing apparatus according to the present invention. Five hundred recording electrodes 201 are interposed between twenty-one pairs of opposed common electrodes 101 to 121.

Figure 7 illustrates the fundamental principle of driving a recording head of a printing apparatus according to the present invention dynamically. As shown in Figure 7(a) recording electrodes 201 to 206 are arranged between respective pairs of oppositely disposed return electrodes 101 to 105. A pair of return electrodes will hereinafter be referred to as a return electrode.

Figure 8 illustrates an equipotential surface in a conductive layer of a thermal printing sheet used with a printing apparatus according to the present invention when applying different potentials to neighbouring return electrodes. The recording head is in contact with the thermal printing sheet 1 (Figure 1) and potentials $E(v)$ and $0(v)$ are respectively provided to the return electrodes 101, 102. As shown in Figure 8 no electric field is produced in the region 911 between the return electrodes 102. Therefore, for example, when $0(v)$ potential is

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simultaneously applied to recording electrodes 913, 914, current flows from the recording electrode 913 to the return electrode 101, whilst current does not flow into the area around the recording electrode 914 because it is at the same potential as the return electrode 102. In this case, printing is performed by the recording electrode 913 but not by the recording electrode 914. Such an arrangement of the return electrode permits the potential of the return electrode and the recording electrode to be selected, which results in selective printing.

Referring back to Figure 7(b) which illustrates the principle of operation of a printing apparatus according to the present invention, selective signal electrodes 301, 302, 303 are respectively connected to recording electrodes 201, 206 through respective diodes 501 to 506. A selective signal S1 of 0(v) is applied to the selective signal electrode 301 and selective signals S2, S3 are non-selected, floated and applied to the selective signal electrodes 302, 303 and 0(v) or E(v) is simultaneously and selectively applied to the return electrodes 101 and 103. No matter the potential applied to each return electrode, no electric field is formed between a pair of opposed return electrodes. Therefore, printing can be selectively effected with the recording electrodes 201 and 202. On the other hand, although a closed loop is respectively provided between the non-selected recording electrodes 203, 204, 205, 206 and the return electrode 101, current is prevented from

flowing by the diodes 503, 504, 505, 506. Therefore, printing is not effected. In case of selecting the selective signal electrodes 302 or 303, the recording electrodes 203, 204 or 205, 206 are respectively disposed between the return electrodes 101 and 102, 103 and 104 or 102 and 103, 104 and 105 as shown in Figure 7(b) so that the recording electrodes are influenced by the adjacent return electrodes.

In order to avoid this influence, the neighbouring electrodes are driven in pairs. For example, when selecting the selective signal electrode 302, two pairs of return electrodes 101 and 102, 103 and 104 are energised. When selecting selective signal electrode 303, two pairs of return electrodes 102 and 103, 104 and 105 are energised. In this way, all the recording electrodes can be driven. Actually, one sub-scanning period is separated into a first half period and a second half period. Therefore, the return electrodes such as 101 and 102, 103 and 104 are driven in pairs in the first half period and the return electrodes such as 102 and 103, 104 and 105 are driven in the second half period.

When different potential levels are applied to a pair of return electrodes, current flows between the return electrodes. However, this does not interfere with the operation, since the current density of the return electrodes, whose area is sufficiently larger than that of the recording electrode, is very small.

In order to print a line of characters or produce a printed image, an irregular dynamic driving system as described below is used for driving a different pair of adjacent return electrodes in the first half period and the second half period.

5 Namely, when M selective signal electrodes and $(2N + 1)$ return electrodes are utilised, $M + (2N + 1)$ driving circuits can drive $M \times N$ recording electrodes. At this time, a printed image or a printed character can be produced using N recording electrodes at the same time during one selective period, and the duty is
10 $1/M$. Assuming the same speed applied to a conventional multi-head printing apparatus, the selective period of a printing apparatus according to the present invention is N time greater. Thus, electric power can be greatly reduced. Further, manufacturing cost can also be reduced by decreasing the number
15 of driving circuits.

The shape of the electrodes of the printing apparatus according to the present invention is similar to that of a conventional multi-stylus static electric printer that is to say, pin shaped. The conventional multi-stylus static
20 electric printer cannot be dynamically driven for the reason discussed hereinafter.

Figure 9 illustrates a conventional multi-stylus static electric printer where a selective signal C_1 to C_5 is fed to return electrodes 101 to 105, and recording electrodes are
25 divided into a group 20 and a group 21 which are alternately

driven.

Figure 10 illustrates the potential distribution created in a conductive layer of a thermal printing sheet when the multi-stylus static electric printer of Figure 9 is driven.

5 For example, opposed return electrodes 101 are set to $E(v)$, adjacent recording electrodes 207, 208, 209 are set to $0(v)$ and the other recording electrodes are in the floating state. In this case, current density decreases compared with the case that only one recording electrode is set to $0(v)$, since a
10 potential gradient is not created among recording electrodes at $0(v)$. In particular, little current flows into the central recording electrode 208. As a result, variation in print density or voids in the printed image is caused.

When driving a printing apparatus according to the present
15 invention, selective signal electrodes 301 to 318 are selected, and a signal voltage corresponding to data is simultaneously supplied to the return electrodes 101 to 105. Thereby only one recording electrode is selected for each pair of return electrodes. As a result there is no void in the electric field. It will
20 be appreciated that a printing apparatus according to the present invention is based on a driving principle which is quite different from that of a conventional multi-stylus static electric printer.

Referring back to the printing apparatus shown in
25 Figure 6(a), $l_1 = 4.4\text{mm}$, $l_2 = 0.6\text{mm}$, $l_3 = 1\text{mm}$ and pitch P_2 between recording electrodes is $200\text{ }\mu\text{m}$. Figure 6(b) illustrates

driving of the printing apparatus of Figure 6(a). Therein
M = 50 and N = 10 for dynamic driving and the recording
electrodes $N \times M = 500$ are driven using 50 of the selective
signal electrodes 301 to 350 and $(2N + 1) = 21$ return electrodes
5 101 to 121. The recording electrodes having a density of 5
dots per mm are arranged 10 cm in width between centres of
adjacent return electrodes 101 to 121. Therefore, when the
selective signal electrodes 301 to 325 are selected, the
return electrodes are driven in combinations of 101 and 102,
10 103 and 104, ... 119 and 120 respectively. When the selective
signal electrodes 326 to 350 are selected, the return electrodes
are driven in combinations of 102 and 103, 104 and 105 ... 120
and 121 respectively. Normal printing can be carried out even
when the recording electrodes are disposed between adjacent
15 return electrodes.

Figure 11 illustrates a timing chart of driving waveforms.
Selective signals S1 to S50 are fed to selective signal electrodes
301 to 350 respectively. A potential of high level is set to
0(v) and a potential of low level is floating. For example
20 when a signal 930 is high level, the signals corresponding to
written data are fed by driving the return electrodes in combinations
of 101 and 102, 103 and 104 ... 119 and 120. When the signal 930
is low level, the signals corresponding to the written data are
fed by driving the return electrodes in combinations of 102 and
25 103, 104 and 105, ... 120 and 121. Thus 16 gray scales can be

realised by modulating the pulse width of the voltage applied to the return electrodes 101 to 121 by 16 steps.

Figure 12 is a block diagram of an embodiment of a printing apparatus according to the present invention. A control circuit
5 941 delivers a line starting signal 931 and a request clock signal 932 (500 pulses per second) into a picture signal generating circuit 940. Being synchronised with the request clock signal 932, a picture element data signal 950 is fed to an address of a ROM table 942 which is for treating image picture
10 such as a gamma curve compensation. The table for treating the image picture corresponding to each colour and each output content is selected by a multi-bit signal 951 from the control circuit 941. An 8-bit picture element data signal 952 is transmitted under control of a clock signal 933 to a shift
15 register 944 consisting of ten 8-bit registers connected in line. A preset counter 945 is set by a signal 934 from the control circuit 941. The preset counter 945 includes ten 8-bit input counters and reforms the pulse width corresponding to the inputted data by counting a clock signal 953. A flip-flop
20 circuit 946 is set by a carry signal provided from the preset counter 945 with a setting signal 935 and delivers a pulse which corresponds to the inputted data and whose pulse width is modulated. Thus, selection of 256 gray scales is permitted, though there are actually 16 gray scales generated by a 4-bit
25 signal. Therefore 5 to 6 bit signal is used in the example in Figure 5(a). The modulated pulse selects two adjacent return

electrodes from the return electrodes 101 to 121 under control of a signal 930 fed to a distributing circuit 947 and then is inverted to a driving voltage in a driving circuit 948 to be fed to the 21 return electrodes 101 to 121.

5 Selecting signals S1 to S50 are generated by a clock signal 958 and a timing 959 through a 50-step shift register 949. The selecting signals are fed to the selecting signal electrodes 301 to 350 through an open-collector high voltage driver 960. The waveform of the signals 931 to 935 is shown in
10 Figure 11.

 Figure 13 illustrates a driving circuit of a printing apparatus according to the present invention in which a block 32 is a pulse width modulator as shown in Figure 5(a). Figure 14 is a timing chart of signals appearing in the driving circuit of
15 Figure 13.

 In the case of this embodiment, data of 6 bits per element is stored in the memory 12 of 500 words per line. Every ten data are read out during a period with 1/50 duty and are modulated to data of 5 bits per element in a gamma modulation
20 tabel and applied to a shift register 35 of 5 bits in ten steps in parallel so as to be modulated to the pulse width as described above. Ten signals 31 whose pulse width is modulated are divided into twenty-one signals 38 through a selecting gate 33, and subsequently are divided into twenty-one common electrode
25 signals 39 through a driver 34.

An embodiment of the selecting gate 33 is illustrated in Figure 15, and an example of the driver 34 is illustrated in Figure 16, where an inverter 51, a NAND gate 52, a capacitor 53, a resistor 54, a transistor 55 and a diode 56 are shown.

5 Signals at respective outputs 601 to 621 of the selecting gate 33 are respectively applied to the common electrodes 101 to 121 through the driver 34. For example, when a selective signal 37 from the block 32 is low level during the first half period, signals 701 to 710 which respectively modulated are applied to
10 pairs of outputs 601 and 602, 603 and 604, ... 619 and 620.

In the driver 34, the signal 38 of 5V from the selecting gate 33 is level-modulated to $V_H = 40V$ through a first pair of complimentary transistors, and subsequently is current-amplified through a pair of emitter-follower transistors.

15 Control signals 40, 41 from the block 32 are applied to the shift register 35 so as to form a selecting signal 42 of 1/50 duty, and then are applied to the selective signal electrodes 301 to 350 through a driver 36 which produces signals 43. Figure 17 illustrates the driver 36 which is a switching circuit.
20 The switching circuit turns ON when the signals 401 to 450 are high level and current flows from the common electrodes.

In order to effect full-colour printing using a printing apparatus according to the present invention a heat fusible ink having bands of yellow, magenta and cyan colour constituents
25 is transferred onto a recording medium. As a source of an input signal there is a possibility of

using a television signal of a still picture,
a signal from a full-colour scanner, from a personal computer
or the like. In one embodiment of the present invention a NTSC
television signal is utilised for the input signal.

5 Figure 18 is a block diagram of a picture signal generating
circuit for a printing apparatus according to the present invention.
A NTSC composite signal 83 is split into a red signal 86, a green
signal 87, a blue signal 88 through a decoder 71 and fed to a
change-over switch 73. The signals 88, 87, 86 are switched over
10 in order at every page by a change-over switch 73 with a change-
over signal 93, so that full-colour printing is effected in order
of yellow, magenta and cyan at every page. The line printing
speed is set to 60Hz. One horizontal analogue signal is converted
from a digital signal per field of the television signal in an
15 A/D converter 74 to produce a 6-bit data signal 90. After
passing through a latch circuit 75, the latched signal is
alternately stored in a memory 81 and a memory 82. Thus, the
number of memories can be reduced. When data is written in the
memory 81, data is read from the memory 82. Therefore, the
20 image data 21 is supplied to a pulse width modulator as shown
in Figures 4 and 5 without loss in time by alternately driving
two line memories. These operations are controlled by a
horizontal synchronising signal 84, a vertical synchronising
signal 85 delivered from a sync pulse separator 72, control
25 signals 96, 97 for controlling write gates 77, 79 and read

gates 78, 80 generated in a control circuit 76 by the request signal 23 from the pulse width modulator, and memory control signals 98, 99. The decoder 71, the change-over switch 73, the A/D converter 74, the latch circuit 75, the sync pulse generator 72 and the control circuit 76 correspond to the image signal generator 10 in Figure 5 (a). The memories 81, 82 correspond to the memory 12 of Figure 5(a). The image data 21 is fed to the gamma compensation table 13 in Figure 5(a).

Figure 19 illustrates the basic concept of a full-colour printing apparatus according to the present invention. A record medium 808 is wound onto a roller 800. A thermal printing sheet 1 is supplied from a supply reel 802 through transfer reels 805. The thermal printing sheet is in contact with the record medium on the roller 800 and recorded by a recording head 801. The recording head is pressed against the roller by a spring 812 in order to keep a suitable pressure therebetween. As a result, the thermal printing sheet is kept in uniform contact with the record medium.

Figure 20 shows the thermal printing sheet on a roll. Heat fusible ink consisting of a yellow band 813, a magenta band 814, a cyan band 815 and a black band 816 are transferred onto the record medium for every page. Therefore, four printing operations are necessary to obtain a page printed in full colour. When one colour ink is placed over another, the position of the record medium must be determined very precisely.

The black band 816 is not always required since black can be formed by mixing ink from the bands 813, 814, 815.

Referring back to Figure 19, a rotary encoder 811 decides the absolute position of the record medium. A positioning signal is delivered from the rotary encoder 811 to a control circuit 810. One signal from the control circuit 810 is fed back to the roller 800 for maintaining rotation at constant speed. Another signal is delivered to the reel 802 for supplying a sheet of thermal printing paper. A third signal is delivered to a take-up reel 803. Another signal is delivered to a record head driving circuit 804. Thus the record medium is precisely positioned. The positioning signal delivered from the rotary decoder 91 is fed to the control circuit 76 (Figure 18) and synchronised with the change-over signal 93. A sheet transfer signal is supplied from the control circuit 76 in Figure 18 to the control circuit 810 for driving the roller 800 in synchronism with the change-over signal.

In one practical embodiment of a printing apparatus according to the present invention full colour printing in 32 gray scales of a television picture could be effected in 30 seconds by printing yellow, magenta and cyan fusible ink on a record medium, the applied voltage being 40V. In this case, black ink was not utilized.

In the above described embodiment of the present invention recording electrodes of the pin type and planar return electrodes are utilised but it is clear that the present invention is not

limited thereto as shown in Figure 21 where the voltage is applied between pin-type electrodes. The contacting end portion of pin-type electrodes with the resistive layer are indicated by reference numerals 240, 241. Contact of electrodes with a power supply 268 is controlled by switches (k-1) to (k+2).

Arrows 254, 255 in Figure 21(a) represent the direction of current flow. Figure 21(b) is an equivalent circuit. An open switch is indicated by reference numeral 257 and a closed switch is indicated by reference numeral 258. Thus current flows as indicated by arrows 254, 255. Each electrode is selected and controlled by the switches (k-1) to (k+2). Printing in parallel as already described is possible using dynamic driving.

Figure 22 illustrates the construction of a printing head which is of the pin type of a printing apparatus according to Figure 21. A Ni-Cr layer 261 and Cu layer 262 are deposited on a ceramic substrate 260 and etched photochemically to form electrodes. Then a Ni-W-P layer 263 is selectively coated on the electrodes by electroless plating.

The thermal printing sheet used in the first embodiment of the present invention consists of an ink layer disposed on one surface of an insulating supporting layer and a resistive layer disposed on the other surface thereof. In this embodiment, thermal printing sheets as shown in Figure 23 may be used. In Figure 23 the thermal printing sheet (a)

has an ink layer 901 directly supported by a resistive layer 902. The thermal printing sheet (b) has an insulating layer 903, which is made of resin for example, interposed between the ink layer 901 and the resistive layer 902 for preventing unsuitable colour mixing. The thermal printing sheet (c) is a single layer sheet wherein the resistive layer is incorporated into the ink layer. The resistive layer is formed by binding carbon particles with resin. The resistance value of the resistive layer is preferably 100Ω to 500KΩ.

The printing apparatus according to the present invention and described above can perform full-colour gray scale printing by modulating the pulse width of the driving voltage with high reliability. A particular feature of the present invention is that current flows between two electrodes connected with a resistive layer of a thermal printing sheet including an ink layer either incorporated into the resistive layer or separate therefrom. Rapid gray scale printing is obtained even though the number of memories is reduced, by using means which varies the pulse width of the applied voltage according to a gray scale command signal.

In the embodiment of the present invention described herein, a NTSC television signal has been utilised but it is clear that the present invention is applicable to other sources of input signal such as full-colour printers, full-colour copiers and full-colour television printers etc.



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CLAIMS

1. A printing apparatus comprising: an ink sheet member including at least a resistive layer and an ink layer; a head including a first electrode and at least a second electrode, said first and second electrodes being, in operation,
5 in contact with said resistive layer of the ink sheet member and connected to a drive circuit for causing current to flow through said ink sheet member; and a control circuit including a gray scale signal generating means and a pulse width setting means for modulating the pulse width of the voltage applied to said
10 electrodes in response to said gray scale signal, said head and said ink sheet member being so arranged that the current flowing through said ink sheet member passes through said resistive layer.
2. A printing apparatus comprising: an ink sheet member
15 including at least a resistive layer and an ink layer, said ink layer being disposed to be opposed to record medium and having a plurality of different coloured ink constituents; a head including a first electrode and at least a
20 second electrode, said first and second electrodes being, in operation, in contact with said resistive layer of the ink sheet member and connected to a driving circuit for causing current to flow in the ink sheet material; and a control circuit including a colour signal generating means for generating
25 three colour signals according to three primary colours, and a pulse width setting means for modulating the pulse width



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of the voltage applied to said electrodes in response to said three colour signals, said head and said ink sheet member being arranged so that the current flowing in the ink sheet member flows through the resistive layer to transfer the coloured ink constituents of said ink layer onto the record medium in response to said three colour signals.

3. A printing apparatus as claimed in claim 1 or 2 in which said ink sheet member has an insulating support layer between said resistive layer and said ink layer.

4. A printing apparatus as claimed in claim 1 or 2 in which said ink sheet member consists solely of said resistive layer and said ink layer.

5. A printing apparatus as claimed in claim 1 or 2 in which said ink sheet member comprises said resistive layer and said ink layer which are formed as a single layer.

6. A printing apparatus as claimed in any preceding claim in which a plurality of said first electrodes are arranged in a line between a plurality of pairs of said opposed second electrodes, the control circuit being arranged to drive said first and second electrodes by time-sharing.

7. A printing apparatus as claimed in any preceding claim in which the first electrode is of a pin shape and each second electrode is planar.



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8. A printing apparatus as claimed in any of claims 1 to 6 in which the first and second electrodes are of a pin shape.

9. A printing apparatus as claimed in claim 2 or
5 any of claims 3 to 8 when dependent thereon in which said ink sheet member has a plurality of transverse bands of ink of different colour arranged thereon.

10. A printing apparatus as claimed in claim 2 or any
10 of claims 3 to 9 when dependent thereon comprising detection means for detecting the relative position of said ink sheet member and said head to transfer different colour ink from the ink layer to the portion of the record medium beneath the head.

11. A printing apparatus as claimed in claim 2 or any
15 of claims 3 to 10 when dependent thereon in which the ink layer comprises yellow, magenta and cyan colour constituents.

12. A printing apparatus as claimed in claim 2 or
any of claims 3 to 10 when dependent thereon in which the ink layer comprises yellow, magenta, cyan and black colour
20 constituents.

13. A printing apparatus as claimed in any preceding claim in which the or each second electrode is formed of a pair of planar electrodes.

14. A printing apparatus substantially as described
25 with reference to and as shown in Figures 1 to 8 and 11 to 23 of the accompanying drawings.