

PRINTING APPARATUS

This invention relates to a printing apparatus.

The present invention seeks to provide a printing apparatus for printing a colour TV picture image, to provide an economical printing apparatus with relatively high printing speed, quality
5 and reliability without using expensive silver-halide film and providing a printing apparatus producing colour printed pictures in similar manner to a colour printer or hard copy colour graphic processor.

Currently colour display devices for displaying information
10 are being improved. Research is being conducted into various forms of colour printing apparatus. For example, there has been proposed ink jet printing apparatus, thermal transfer printing apparatus and wire dot printing apparatus. Although these printing apparatus have various disadvantages, it is possible to adapt
15 them for colour printing in several colours (about 7 to 16 colours) but it is difficult to print a colour TV picture image and to provide an economic and dependable printing apparatus having a relatively high printing speed and quality. The reason for this is simply that any of the aforesaid printing apparatus use
20 a two-level recording method (a three or four level recording method is occasionally possible depending upon circumstances), wherein a dot is printed or not. Therefore, when representing a grey scale, it is necessary to use a signal process such as a

dither method or a matrix area grey scale method in which several dots are formed as a unit. These methods result in an increase of costs and a decrease in printing speed and quality. In order to solve such problems a multi-level recording method is necessary.

5 According to the present invention there is provided a printing apparatus for printing from an ink film carrier having at least a resistive layer and a fusible ink layer, the apparatus comprising a recording head having a plurality of recording styluses arranged in a line, alternate recording styluses are each associated with
10 a respective first switch arranged to be connected to a relatively high potential and the other alternate recording styluses are each associated with a respective second switch arranged to be connected to a relatively low potential, the arrangement being such that, in operation, the switches associated with a pair of adjacent recording
15 styluses are closed simultaneously to cause current to flow in the resistive layer of the ink film carrier whereby the resultant heat generated causes partial melting of the ink layer so that ink can be transferred to a transfer sheet to form a picture element.

 Preferably the picture elements in a line are divided in N
20 groups of picture elements, where N is an odd integer equal to or greater than 3, each group comprising picture elements spaced by N - 1 picture element locations, N groups of picture elements being printed with time difference.

The printing apparatus may include means for varying the length of time current is caused to flow in the resistive layer to control the quantity of ink layer melted.

- 5 The styluses may be formed on a ceramic substrate or alternatively on a glass-epoxy substrate.

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

- Figure 1, consisting of Figures 1(a), 1(b) and 1 (c),
10 illustrates examples of ink film carriers used for thermo-electric transfer recording;

Figure 2, consisting of Figures 2(a), 2(b) and 2(c), illustrates the fundamental principle of multi-level thermo-electric transfer recording;

- 15 Figure 3 shows schematically a printing head having a plurality of recording styluses, and Figure 4 is an equivalent electrical circuit diagram thereof;

Figure 5 shows schematically a printing head for a printing apparatus according to the present invention;

- 20 Figure 6 shows schematically a printing apparatus according to the present invention incorporating the recording head of Figure 5;

- Figure 7, consisting of Figures 7(a), 7(b) and 7(c), illustrates the fundamental principle of grey scale recording using
25 the printing head of Figure 5;

Figure 8 shows the control of a plurality of adjacent recording styluses in a printing apparatus according to the present invention, and Figure 9 is an equivalent electrical circuit diagram thereof;

5 Figure 10, consisting of Figures 10(a), and 10(b), illustrates the fundamental principle of a printing apparatus according to the present invention;

Figure 11, consisting of Figures 11(a) and 11(b), shows the control of switches in the arrangement of Figure 10;

10 Figure 12, consisting of Figures 12(a), 12(b) and 12(c), illustrates the formation of a line of picture elements with the arrangement of Figure 10;

Figure 13, consisting of Figures 13(a) and 13(b), illustrates further the printing apparatus of Figure 10;

15 Figure 14, consisting of Figures 14(a) and 14(b), illustrates the fundamental principle of switching in a printing apparatus according to the present invention;

Figure 15, consisting of Figures 15(a) and 15(b), illustrates cross-talk in a printing apparatus according to the present invention;

20 Figure 16 is a perspective view of part of a printing head of a printing apparatus according to the present invention;

Figure 17 is a plan view of the printing head of Figure 16;

Figure 18 illustrates an ink film carrier for use with the recording head of Figure 16;

25 Figure 19 is a block diagram of the circuitry of one embodiment of a printing apparatus according to the present invention;

Figure 20 is a block diagram of a shift register forming part of the circuitry shown in Figure 19;

Figure 21 and Figure 22, consisting of Figures 22(a) and 22(b), illustrates switches of the printing apparatus of Figure 19;

Figures 23 to 25 are timing charts illustrating the operation of the printing apparatus of Figure 19;

Figure 26 shows part of a printed image picture produced by the printing apparatus of Figure 19;

Figure 27 is a timing chart illustrating the operation of another embodiment of a printing apparatus according to the present invention;

Figure 28 is a block diagram of a further embodiment of a printing apparatus according to the present invention;

Figures 29 and 30 are circuit diagrams of a selector and switches of the printing apparatus of Figure 28; and

Figure 31 is a perspective view of another form of printing head for a printing apparatus according to the present invention.

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

Figure 1 shows several examples of an ink film carrier used for thermo-electric transfer recording. A fusible ink layer 1 is formed by dispersing a pigment, or a pigment together with a dye, in wax and has a fusing temperature of about 60°C. A layer 2 is a resin film, for example of PET, or a condenser paper, which

is used as an ink support layer in Figure 1(a). A resistive layer 3 is formed by dispersing carbon powder in a resin to give it electrical conductivity. In Figure 1(b) a resistive layer 4 having electrical conductivity supports the ink layer 1 directly. In Figure 1(c), a layer 5 for preventing colour turbidity is made of resin with heat-resistant properties. Heat, which is generated by causing current to flow through the resistive layer of each of the ink film carriers causes localised melting of the fusible ink in the ink layer 1 and thereby forms a picture element on a transfer sheet.

Figure 2 illustrates the fundamental principle of multi-level thermo-electric transfer recording. Figure 2(a) is a cross-sectional view of an ink film carrier 19 having the construction of Figure 1(a). There is provided an ink transfer sheet 10, a recording stylus 6, a common electrode 7, a power source 8 and a switch 9. Closing the switch 9 causes current indicated by reference numeral 11 to flow through the resistive layer 3. Figure 2(b) depicts the distribution of the current 11 which flows in the resistive layer 3. The heat generated is in proportion to the square of the current density, and the resulting temperature distribution is depicted in Figure 2(c). The temperature distribution depends on the period of time for which the switch 9 is closed, as depicted by curves 12,13 in Figure 2 (c). The curve 12 corresponds to the case where the period of time for which the switch 9 is closed is relatively short and the curve 13 corresponds to the case where the period of time for which the switch 9 is closed is

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relatively long. If the melting point of the fusible ink in the ink layer 1 is T_m , the fusible ink in the ink layer is melted in the region where the temperature is higher than T_m , and the melted ink is transferred to the transfer sheet 10. The area of transferred ink, as shown by areas 15,16 respectively, corresponds to the temperature distribution shown by curves 12,13. In this way, variations of the periods of time for which current flows in the ink film carrier enables multi-level recording.

Another important point is recording at high speed. In order to realise high speed recording each of a plurality of styluses operates simultaneously to effect recording. Figure 3 shows a printing head having a plurality of recording styluses 6. Figure 4 is a simplified equivalent electrical circuit diagram of the printing head of Figure 3. Each recording stylus is connected to the power source 8 through a respective switch 9. An equivalent resistor 17 with a resistance r_1 is located between each recording stylus 6 and the common electrode 7. An equivalent resistor 8 with a resistance r_2 is present between adjacent recording styluses.

Except in the case where $r_1 \ll r_2$, the magnitude of the current and the direction of current flow through each recording stylus depends on whether the switches 9 are closed or opened, and it is impossible to control current flow through each recording stylus by opening or closing only one switch corresponding to that recording stylus. Further, even where $r_1 \ll r_2$, it is very difficult to make electrical connection uniformly between the resistive layer

and the common electrode for many recording styluses as shown in Figure 3. That is to say, to put into practice multi-level recording with a plurality of recording styluses using an ink film carrier having a resistive layer, the following two points must be satisfied:

- 5 first, the electrical connections must be made uniformly without any error, and secondly recording must be performed with a plurality of recording styluses simultaneously.

Figure 5 shows a printing head 22 for a printing apparatus according to the present invention. From the point of view of
10 reliability, the recording head should have heat resistant properties and permanence, and so it is desirable to use a ceramic material for substrate 20, though more commercially economic materials such as glass-epoxy can be used in certain circumstances. The recording head 22 has a plurality of recording styluses 21, the number being
15 dependent upon the signals to be recorded. For example, for recording a colour TV picture image about 500 styluses in a line are necessary.

Figure 6 shows a printing apparatus according to the present invention incorporating a printing head 22 of Figure 5. A main
20 roller 30 is formed of elastomeric material such as rubber, around which the transfer sheet 10 is wrapped and fixed by a fixing device 32. An ink film carrier 19, such as shown in Figure 1(a), is stored on a reel 33 and taken up by a reel 34. Reels 35,36 are provided for guiding the ink film carrier 19. An end face 23 of the printing
25 head 22 is pressed against the main roller 30 by a spring 37, the printing head being pivotally mounted at a point 38. Pressing the

printing head of Figure 5 against the ink film carrier 19 results in a complete electrical connection between the styluses and the resistive layer of the ink film carrier. As shown in Figures 5 and 6, only the styluses of the printing head are used for recording so that it is possible to make excellent and reliable electrical contact with the resistive layer of the ink film carrier. Moreover, as the styluses and the substrate 20 are made as a unitary structure, no problems such as damage to the styluses occurs and this results in remarkable reliability.

10 The fundamental principle of grey scale recording using the printing head of Figure 5 having excellent contact reliability will now be described. Figure 7(a) shows the flow of current 42 in the resistive layer, which includes an area 40 in contact with one of the styluses to which a relatively low voltage is applied and an area 41 in contact with one of the styluses to which a relatively high voltage is applied. In the same manner as shown in Figure 2, the temperature distribution depends on the period of time for which the current flows and is depicted by curves 43,44 in Figure 7(b). The curve 43 represents the condition where the period of time for which the current flows is relatively short and the curve 44 represents the condition where it is relatively long. Therefore, the ink transferred to a transfer sheet is as illustrated by areas 45,46 in Figure 7(c).

Figure 8 shows the control of a plurality of adjacent recording styluses in a printing apparatus according to the present invention. Switches 50 connected to the positive side of the power source 8

and switches 51 connected to the negative side of the power source are alternately used to connect stylus electrodes $H_1 - H_m$ with stylus electrodes $L_1 - L_m$. The number of stylus electrodes is $2m$ and the number of picture elements is $2m-1$ (m is a positive integer). Hereinafter the switches in the negative side are to be referred to as L switches and the switches in the positive side as H switches. The electrodes connected to the negative side of the power source 8 are L electrodes and the electrodes connected to the positive side are H electrodes. For example, referring to the electrode H_1 , a picture element is formed between the electrodes H_1 and L_1 , and a picture element is formed between the electrodes H_1 and L_2 respectively by causing current to flow between the electrodes H_1 and L_1 and between the electrodes H_1 and L_2 respectively. In this way, picture elements are formed between all of the L electrodes and the H electrodes.

Figure 9 shows the equivalent circuit diagram of Figure 8 with respect to the k -th L electrode. A resistor 52 is disposed between the k -th L electrode and all the H electrodes, and the current flow varies in dependence upon whether the H switches are on or off. This is the same structure as that of Figure 4 which cannot be utilised.

Referring now to Figure 10, the arrows in Figure 10(a) represent the direction of current flow in a printing apparatus according to the present invention, and Figure 10(b) shows an equivalent circuit diagram thereof. The potential of an H electrode 41 and an L electrode 40 is dependent upon whether switches connected

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thereto are opened or closed as shown in Figure 10(b). An open switch is indicated by reference numeral 57 and a closed switch is indicated by reference numeral 58. Under this condition, current flows as indicated by arrows 54,55. At this time, the current indicated by arrows 56,57 cannot flow in principle. Accordingly, only equivalent resistors 53 exist so that the magnitude of current flow is always dependent on the resistance between adjacent electrodes. The equivalent circuit diagram of Figure 10(b) only exists when the direction of current flow indicated by arrows 54,55 is opposite to each other. More particularly, in order to realise the equivalent circuit diagram of Figure 10(b), the period of time for which the H switches are closed must be equal to the period of time for which the L switches are closed. For example, the current indicated by arrow 57 is generated in the case where the k-th H switch and L switch are closed, the (k + 1)th H switch is closed, and the (k + 2)th L switch is opened. Namely, it is not necessary to provide a switch connected to either positive or negative side of the power source such as switches 60, 61 of Figure 11(a) but to provide a switch connected to both sides of the power source such as switch 62 of Figure 11(a). Further, the adjacent H switch and L switch must be opened or closed in response to the same signal as shown in Figure 11(b). In Figure 11(b) reference numerals 63,64,65 represent signals activated by the switches associated with electrodes L_1 and H_1 , electrodes H_1 and L_2 and electrodes L_2 and H_2 respectively. With respect to the signals 63,64,65, the time interval of closing each switch is desirably different from each other. In Figure 10

one-third of all the picture elements in a line can be formed simultaneously. A line of picture elements is formed by recording three times, as shown in Figure 12. By opening or closing each switch as shown in Figure 12, current 70 flows in order through 5 equivalent resistors disposed between adjacent recording styluses, so that a line of picture elements can be wholly formed.

Figure 13(a) illustrates the closed switches only of Figure 12(a) which energise to form all of the three picture elements.

Figure 13(b) shows the case where the middle of three picture elements 10 is not formed, switches 200 being opened. At this time, current flows as indicated by arrows 201 and 202. The magnitude of the current 201 is slightly smaller than that of the current 70, and the magnitude of the current 202 is about 8 to 10% of that of the current 201. When two-level printing is performed, this cross-talk can 15 be ignored but when grey scale printing is performed the cross-talk causes a big problem depending on the number of the grey scale. It is, therefore, desirable that this cross-talk is as small as possible and the present invention seeks to provide an arrangement which reduces or eliminates the cross-talk.

20 In the printing apparatus of Figure 10 a group of picture elements are formed for three picture elements. However, it is preferably that one group of picture elements are formed per N picture elements, that is, picture elements are divided in N groups represented as $N \times J + N$ (J is 0 or a positive integer and N is 25 an odd integer greater than 3) in order from the end, each group of picture elements being formed N times. By setting N to an odd

number of more than 3, there is the advantage that a plurality of picture elements can be simultaneously formed. In addition, the above disadvantage of cross-talk is reduced by increasing N. However, when N become large the number of picture elements that
5 can be formed simultaneously becomes small. In actually determining N it is desirable to select the most adequate value taking into consideration the above two points.

Figure 14(a) illustrates opening and closing of switches in the case where N equals 5 and Figure 14(b) illustrates opening
10 and closing of switches in the case where N equals 7, which corresponds to Figure 12(a). Figure 15(a) illustrates only the closed switches. In Figure 15(b), the middle switch is opened. In this case, the current flows in the same manner as in Figure 13(b). However, the magnitude of the cross-talk current 204 is greatly reduced,
15 that is, to about 2 to 4% in the case of N equals 5 and about 1 to 2% in the case of N equals 7. Cross-talk is reduced as N increases and thus grey scale resolution for grey scale printing is improved.

Figure 16 shows an end portion of a printing head of a first embodiment of a printing apparatus according to the present invention.
20 A Ni-Cr layer 102 and a copper layer 103 are deposited on a ceramic substrate 101 and photo-etched chemically to form electrodes. Then a Ni-W-P layer is selectively coated on the electrodes by electroless plating. This produces a plurality of recording styluses, as shown in Figure 17, there being 320 electrodes $L_1 - L_{320}$ and
25 320 electrodes $H_1 - H_{320}$ (Figure 17) which amounts to 640 electrodes in all. Thus, the electrodes will produce 639 picture elements

$P_1 - P_{639}$. The pitch P of the stylus electrodes is 200 μm . A printing apparatus similar to that shown in Figure 6 using this recording head uses an ink film carrier as shown in Figure 18 consisting of a fusible yellow ink 111, a magenta ink 112 and
5 cyan ink 113 deposited on an ink support layer having a resistive layer 100 on the opposite side.

Figure 19 is a block diagram of the printing apparatus of this embodiment of the present invention. A picture image signal 400 is fed to an input 300, passing through a switch 301 or a
10 switch 302, and is stored in an address of a line memory 303 or a line memory 304 generated from a write-in address generator 305. This picture image signal is read from the address by a read-out address register 306 and fed to a digital comparator 307 where it is compared with a reference signal 321 generated
15 from a grey scale reference signal generator 320. The result of the comparison is fed to a shift register 308 controlled by a shift clock signal 405. Then the signal is transmitted to a temporary memory 309 by a latch clock signal 406, and is delivered to an H switch or an L switch 311 corresponding to a record
20 sequence selecting signal 407 to a distributor 310. This output signal is connected to a recording stylus.

Figure 23 shows the relationship of input and output of picture image signals. A signal 404 controls the switches 301, 302 and is inverted with a line period T_L . The picture image signal 400
25 is formed of signals of 640 picture elements, and is transmitted in a period T_W . The picture image signal 400 is stored in either

the line memory 303 or the line memory 304 by an address signal from the write-in address generator 305 in compliance with an open or closed state of the switch 301 or the switch 302. At this time, an output picture image signal 401 is read from the other line memory
 5 corresponding to the address signal from the read-out address register 306. The signal supplied on a data line of the line memory 303 or the line memory 304 is shown as 402 or 403, respectively. Signals 400 to 403 are parallel signals.

Now write-in address and read-out address will be explained.
 10 Table 1 shows 640 addresses using $\underline{a}_1$ to $\underline{a}_{128}$ and $\underline{b}_1$ to $\underline{b}_5$. Table 2 shows the sequence of write-in address. Picture image signals which are connected in order are stored in the line memory 303 or the line memory 304 corresponding to the sequence shown in Table
 2. Numbering input picture image signals from 1 to 640, the picture
 15 image signal 1 is stored at address 0, the picture image signal 2 is stored at address 128, the picture image signal 3 is stored at address 256, etc. and the picture image signal 639 is stored at address 511 and the last picture image signal 640 is stored at address 639. Read out addresses $\underline{a}_1$ to $\underline{a}_{128}$ vary in order along each block
 20 line $\underline{b}_1$ to $\underline{b}_5$, and the address is read out 16 times per block, since picture image signals of 4 bits having 16 grey scale signals are used in this embodiment. It is the most important requirement for dynamic printing that the addresses are divided into five blocks
 $\underline{b}_1$ to $\underline{b}_5$ as described above. In the case of recording and formation,
 25 picture elements are divided in order from the end into five groups represented as $5J + 1$, $5J + 2$, ... $5J + 5$ (J is 0, 1, ... 128). Thus,

the arrangement of picture image signals is converted by write-in and read-out addresses. According to this embodiment, write-in addresses are divided into five blocks, however, it is possible to read addresses by dividing the reading into five blocks.

TABLE 1

	a1	a2	a3	a4	a5	...	...	a127	a128
b1	0	1	2	3				126	127
b2	128	129	130	131				254	255
b3	256	257	258	259				382	383
b4	284	285	286					510	511
b5	512	513	514					638	639

TABLE 2

	a1	a2	a3	a4	a5	...	...	a127	a128
b1	1	6	11	16				631	636
b2	2	7	12	17				632	637
b3	3	8	13	18				633	638
b4	4	9	14					634	639
b5	5	10	15					635	640

The picture image signal 401 read-out is inputted into the digital comparator 307, compared with the reference signal 321 supplied from the grey scale reference signal generator 320 and

converted to a compared two-level signal of "0" or "1" in compliance with the result of comparison. Picture image signals a_1 to a_{128} per block are read 16 times, and the reference signal 321 varies from 0 to 15 per unit time. Thus, the picture image signal 401 is compared with the reference signal 321 for 128×16 times, which is a period TRA of the picture image signal 401 shown in Figure 23. The period TRA is one-fifth of the line period TL. The compared two-level signal is transmitted to the shift register 308.

Figure 20 is a block diagram of the shift register 308 which is a fundamental circuit for actuating five H switches and five L switches, respectively. In this embodiment 64 fundamental blocks are connected in cascade or in parallel. A D-type flip-flop circuit 500 is used as a shift register and a D-type flip-flop circuit 501 is used as a temporary memory, which reads signals at the rise of a SCK (shift-clock) signal 405 and a LCK (latch-clock) signal 406, respectively. The period of the SCK signal is $TRA/(128 \times 16)$ where a read-out address varies minimally, and the period of the LCK signal is $TRA/16$. These signals are explained with reference to Figure 24. The reference signal 321 consists of a 4 bit signal RCK (reference clock) signal 0 to 3. The RCK signal 0 is the lowest bit and the RCK signal 3 is the highest bit. The reference signal varies from 0 to 15 with a period of TRA during the period TRA, which is repeated. During the period TRA, one block of picture image signals a_1 to a_{128} are outputted and compared. The period of the LCK signal 406 is TRA, and the period of the SCK signal 405 is the same at that during which the above picture image signal

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from the digital comparator 307 is outputted. Referring to Figure 20, the compared two-level signal TA is inputted into a terminal 530, and shifted to the next step in order by the SCK signal 405. Then the compared two-level signal is transmitted to the D-type
5 flip-flop 501 for temporary holding in memory at the after step by the LCK signal 406 so as to be held for the period TRa. At this time, the pulse width of the compared two-level signal is converted by passing through the shift register and the temporary memory, which results in a pulse width picture image signal 540. This signal
10 540 is selected by the record sequence selecting signal 407 opens or closes an L switch 504 and an H switch 505. Reference numeral 502 indicates an AND circuit and reference numeral 503 an OR circuit. PD 531 and ND 532 are connected between the before-step and the after-step. Reference number VH 533 indicates a high potential
15 voltage and VL 534 indicates a low potential voltage.

The L switch and the H switch will be described with reference to Figures 21 and 22. In Figure 21 a switch 522 is opened or closed by a switching control signal 510 so that the potential of a power source line 520 is outputted to an output terminal 521. Figure
20 22a shows the L switch, having a NPN transistor 506, a low potential on a line 511 controlled by the switching control signal 510 is fed to an output line 512. Figure 22b shows the H switch having a NPN transistor and an inversion circuit 508. A high potential on a line 514 is fed to an output line 515.

25 Figure 25 illustrates the record sequence selecting signal 407 which consists of signals SC1 to SC6. The signal SC1 lags

behind the signal 404 for changing over the line memories 303 and 304 in the period TRA approximately. This lag is caused since the switching control signal 510 by passing through the shift register 405 lags for the period TRA behind the output picture image signal read from the line memory 303 or the line memory 304. The record sequence selecting signals respectively open or close the L switch and the H switch in order with a pulse width corresponding to the pulse width picture image signal 540 in compliance with write-in address sequence shown in Table 2.

10 Printing a colour TV picture image was performed using the above-described printing apparatus and the ink film carrier of Figure 18. A colour TV picture image signal converted from an analog to a digital signal, was subsequently stored in a frame memory of 640 x 480 x 3 colours, and then inputted to the input 300 shown
15 in Figure 19. The speed of printing of 8.3 msec for forming one line of picture elements. That is, 480 lines in the whole TV picture were printed in 4 seconds with yellow, cyan and magenta ink, respectively, at the speed of TL = 8.3 msec and TRA = 1.66 msec. As to the printed picture image, almost the same picture quality
20 as that on the CRT TV screen was obtained. Figure 26 illustrates a part of the printed picture image. Arrow 600 indicates the centre of the recording stylus, picture element 601 is formed between recording styluses. Further, the ink film carrier and the transfer sheet were successively moved for printing so that the picture elements
25 were formed in oblique lines. Therefore, a picture image without the scanning lines of the colour TV picture image were obtained.

In a second embodiment of the present invention $N = 7$. The construction is substantially the same as that of the first embodiment. However, the number of recording styluses, the number of picture image signals, etc. are different because $N = 7$. Only the differences in construction will be described in what follows.

The number of recording styluses is 315, which adds up to 630 L and H switches. The number of picture elements is 629. Write-in address sequence is shown in Tables 3 and 4.

TABLE 3

	a1	a2	a3	a4	a5	...	...	a89	a90
b1	0	1	2	3	4			88	89
b2	90	91	92	93				178	179
b3	180	181	182	183				268	269
b4	270	271	272					358	359
b5	360	361	362					448	449
b6	450	451	452					538	539
b7	540	541	542					628	629

TABLE 4

	a1	a2	a3	a4	a5	...	...	a89	a90
b1	1	8	15	22	29			617	624
b2	2	9	16	23	30			618	625
b3	3	10	17	24				619	626
b4	4	11	18					620	627
b5	5	12	19					621	628
b6	6	13	20					622	629
b7	7	14	21					623	630

Table 3 shows 630 addresses using $\underline{a}_1$ to $\underline{a}_{90}$ and $\underline{b}_1$ to $\underline{b}_7$.
Table 4 shows the write-in address generating sequence. Addresses are divided into seven groups to which the second sequence selecting signal SC1 to SC8 correspond, which are shown in Figure 27.

5 Printing a colour TV picture image was performed by using the above-described printing apparatus. The TV picture image signal was stored in a frame memory of $640 \times 480 \times 3$ colours in the same manner as that of the first embodiment. In the line memory 303 or the line memory 304, only 630 of 640 picture elements for a
10 line were stored. Printing was performed at a speed so that a line of picture elements was formed in 8.3 msec, that is, $TL = 8.3$ msec and $TRA = 1.19$ msec. A printed picture image having a very superior quality was obtained.

Figure 28 is a block diagram of a third embodiment of a printing
15 apparatus according to the present invention. A video signal 620 is input into a noise-processing and colour-separating circuit 621 and displayed on a CRT 622. A colour (R, G, B) signal 623 is input into a circuit 625 to correct the inversion gamma and the difference of colour balance between a CRT and the printing
20 apparatus. An adjusting signal 624 is input to the circuit 621 and monitored on the CRT 622. In the circuit 625, signals are corrected to be printed in the colour tone displayed on the CRT. A correcting signal 635 is converted to a six bit data signal in an analog to digital converter 626 and memorised in a line memory
25 628 temporarily. The line memory 628 delivers the signal to a

shift register 629 in response to the signal from a print sequence selecting signal generating circuit 636 wherein 636 dots are sampled from one scanning line. The shift register 629 has 612 steps of 6 bits in parallel, the number of steps being one-third of the number 5 636 given by adding 1 to the number of picture elements 635 on each line.

The line memory 628 outputs the signals to the shift register 629 three times. The signals transmitted to the shift register 629 are memorised and a latch circuit 630, and the pulse width is 10 modulated corresponding to the input data in a circuit 631. Then, in a selector 632, this signal is converted to a signal for opening or closing switches 633 each of which is connected to a stylus electrode 634. The selector 632 has the function of dividing the data whose pulse width is modulated, into each switch 633, in response 15 to a record sequence selecting signal 641 from the print sequence selecting signal generating circuit 636.

Figure 29 shows a detail of a construction of the selector 632 and the switches 633. Data whose pulse width is modulated, is input into a terminal 640 and distributed to switches 646, 647 20 respectively corresponding to the record sequence selecting signal 641 (SC1 to SC4). Reference numerals 642, 643 are buffers of the non-inversion type and of the inversion type respectively, which constitute a tristate driver. A resistor 645 limits the current to a PNP-type transistor which acts as the H switch 646 and to an 25 NPN-type transistor which acts as the L switch 647. Reference numeral 648 (R1 to R6) indicates equivalent resistors of the resistive layer of the ink film carrier. Figure 30 and Table 5 show a fundamental

logic circuit and a logic table of the printing apparatus of Figure 29. "0" and "1" in Table 5 represent L-level and H-level respectively and "HZ" represents a high impedance state.

TABLE 5

D	C	A1	A2	B1	B2
0	0	HZ	HZ	HZ	HZ
1	0	HZ	HZ	HZ	HZ
0	1	0	1	HZ	HZ
1	1	1	0	ON(0)	ON(1)

TABLE 6

	t1	t2	t3
S C 1	1	1	0
S C 2	0	0	1
S C 3	1	0	0
S C 4	0	1	1
selected picture element	R1	R2	R3
	R4	R5	R6

As shown in Table 5, output B1 at terminal 649 of the L switch and output B2 at terminal 650 of the H switch are turned on and current flows from B2 to B1 when D and C are "1".

Table 6 shows record sequence selecting signal 641 (SC1 to SC4) of Figure 29. Signals are distributed to each switch at times

t_1, t_2, t_3 . At time t_1 , current flows through the equivalent resistors R1 and R4 of the ink film carrier of Figure 29. At times t_1, t_2, t_3 the signals of Table 6 are energised as shown in Figure 12(a), 12(b) and 12(c) to form all the picture elements on one line.

- 5 The grey scale record is performed by controlling the period of time for which current flows according to the pulse width of the data signal inputted to the terminal 640. With respect to the selector 632 and the switches 633 in Figure 28, the block represented within a dotted line in Figure 29 is one of 106 stages. The
- 10 equivalent resistor R1 of the first stage corresponds to the picture element P1 of Figure 17 and the resistor R5 of the 106th stage corresponds to the picture element P635. In this embodiment the recording styluses L1 to L318 and H1 to H318 are utilised.

Using the printing apparatus of Figure 28 a printed picture

15 of a colour TV picture image was produced. The equivalent resistance of the resistive layer of the ink film carrier was 4 K ohms.

Printing of a colour TV picture image of 480 lines was effected in 4 seconds by printing fusible ink of yellow, magenta and cyan respectively under an applied voltage of 20 V from the power source

- 20 8. It takes 8.3 msec to form a line of picture elements and the maximum pulse width is 2.7 msec ($2.7 \text{ msec} \times 3 \text{ times} = 8.3 \text{ msec}$). The quality of the printed image picture was almost the same as the quality of the colour TV picture image on the CRT. The printed picture image had a size of 96 x 127 mm. The maximum recording
- 25 energy used to form a picture element was 0.3 mJ (the dot size is about 0.2 x 0.2 mm at the pulse width of 2.7 msec). When printing

all the picture the maximum current flowing was about 1 A and the electrical power consumed by the printing apparatus to produce a complete printed image picture was about 20 W. This energy is one-fifth to one-seventh of that consumed by a conventional thermal head producing the same printed picture image.

A yet further embodiment of a printing apparatus according to the present invention utilises a recording head as shown in Figure 31, which has the same shape as that of Figure 17. A copper layer 661 is coated on a glass-epoxy substrate 660 by electroless plating. An electric coating layer of copper 662 was formed thereon and photo-etched chemically to form electrodes. Then an oxide film on the electrodes was removed using 5% dilute sulphuric acid and soaked in palladium chloride solution before rinsing. A Ni-W-P plating solution was used to provide a Ni-W-P plating layer 604 on the copper electrodes. Using this printing head in the same way as the first two embodiments of a printing apparatus according to the present invention substantially the same recording characteristics with respect to picture quality were obtained. When applying electric power which is approximately three times that required for printing and effecting printing continuously, the recording styluses separated from the glass-epoxy substrate. However, compared to the first embodiment of a printing apparatus according to the present invention where the printing head used a ceramic substrate, there is the great advantage that the picture image quality is good and the printing head can be made at much reduced cost.

The embodiments of printing apparatus according to the present invention described above are very economical, permit a printed image picture of a colour TV picture image to be produced at high speed using a relatively simple recording head, a power source
5 of relatively low capacity and a relatively low load driving circuit. Moreover, grey scale recording with a pair of L electrodes and H electrodes is possible.



CLAIMS

1. A printing apparatus for printing from an ink film carrier having at least a resistive layer and a fusible ink layer, the apparatus comprising a recording head having a plurality of recording styluses arranged in a line, alternate recording styluses are each
5 associated with a respective first switch arranged to be connected to a relatively high potential and the other alternate recording styluses are each associated with a respective second switch arranged to be connected to a relatively low potential, the arrangement being such that, in operation, the switches associated with a pair
10 of adjacent recording styluses are closed simultaneously to cause current to flow in the resistive layer of the ink film carrier whereby the resultant heat generated causes partial melting of the ink layer so that ink can be transferred to a transfer sheet to form a picture element.
- 15 2. A printing apparatus as claimed in claim 1 in which the picture elements in a line are divided in N groups of picture elements, where N is an odd integer equal to or greater than 3, each group comprising picture elements spaced by N - 1 picture element locations, N groups of picture elements being printed with time difference.
- 20 3. A printing apparatus as claimed in claim 1 or 2 including means for varying the length of time current is caused to flow in the resistive layer to control the quantity of ink layer melted.
4. A printing apparatus as claimed in any preceding claim in which the styluses are formed on a ceramic substrate.



5. A printing apparatus as claimed in any of claims 1 to 3 in which the styluses are formed on a glass-epoxy substrate.

6. A printing apparatus substantially as herein described with reference to and as shown in Figures 5 to 31 of the accompanying
5 drawings.
