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(54) Method and apparatus for controlling a heating element of a thermal head

(57) A control apparatus for controlling a heating element of a thermal head (10) has a print data processing unit (40) and a drive control circuit (50). The print data processing unit (40) has a first processing function for converting first color data to first and second print data, a second processing function for converting second color data to second print data, a first line buffer (43) for storing the first print data, and a second line buffer (44) for storing the first and the second print data. The print data processing unit (40) selectively outputs print data from the first line buffer (43) or print data from the second line buffer (44) to the drive control circuit. The drive control circuit (50) has a print buffer (52) and history buffer (53), and energizes the heating elements of the thermal head (10) based on energizing commands determined by a comparison of the content of the print buffer (52) with that of the history buffer (53).

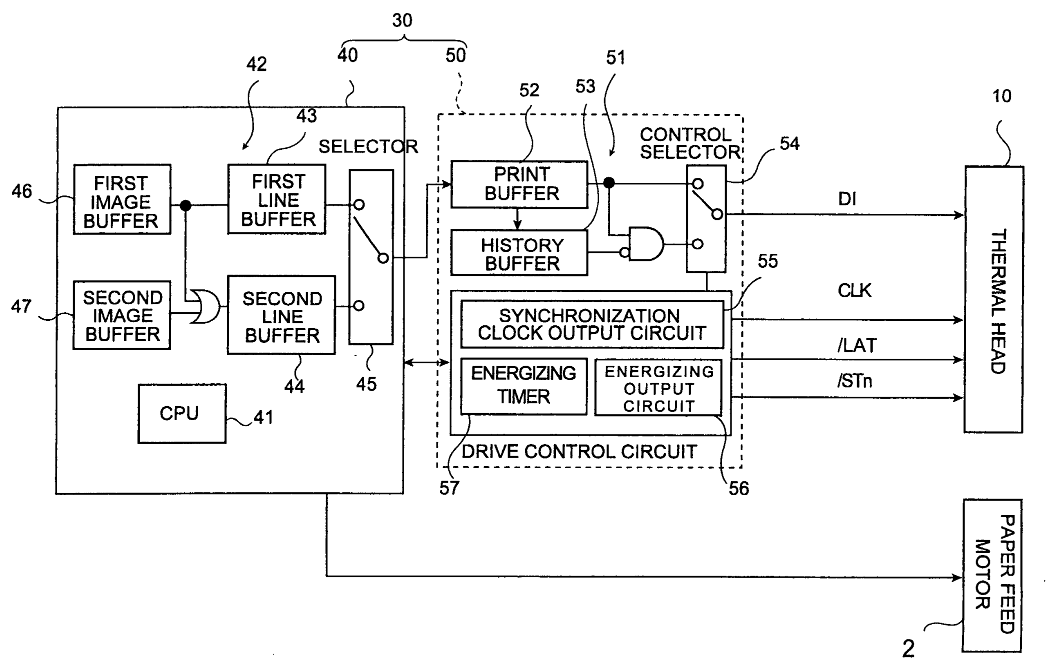

FIG. 1

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Description

[0001] The present invention relates to a technology for controlling the amount of heat applied by a heating element in a thermal head of a printer.

[0002] Generally speaking a thermal head prints by selectively energizing its heating elements by a specified current the resulting heat forming a dot pattern on thermal paper. The amount of heat generated by each energized heating element is controlled by regulating the duration of energizing, i.e., the energizing pulse width.

[0003] The thermal head has a heat storage characteristic such that heat accumulates as current supply to the same heating element continues. Thermal history control is therefore applied to keep the heat output of the heating element constant by controlling the energizing pulse width according to the history of energizing the heating element.

[0004] This thermal history control transfers one line of current print data for each heating element row to a print buffer for temporary storage while the corresponding line of immediately preceding print data is supplied to a history buffer to be stored as history data. A logic operation is then performed on the print buffer data and history buffer data in order to determine the energizing pulse width for each heating element to print the current print data, short pulse width data is then sent to the thermal head for heating elements that operated (printed) immediately before, and normal pulse width data is applied to the thermal head for heating elements that did not print immediately before.

[0005] Thermal paper has a paper base with a heat-sensitive coating that produces color when a certain amount of heat is applied. Two-color thermal paper produces different colors depending on the amount of heat applied, a first color in response to a first (higher) temperature and a second color in response to a second (lower) temperature. When this two-color thermal paper is used with the above-described thermal head it is desirable to be able to selectively use a two-color mode for printing two colors (such as black and red) and a monochrome mode for printing only one color (e.g., black). To print two colors it is necessary to selectively generate either long energizing pulses for high heat output and short energizing pulses for low heat output.

[0006] The problem with this is that the circuit for controlling energizing the heating elements becomes complex when it is adapted to two-color printing on two-color thermal paper. A further problem with two-color printing is that the second color appears like a ghost around the edges of the first color. It is assumed that this problem is caused by insufficient time for the heat generated by heating elements to distribute sufficiently so that temperature distribution of the entire area of a respective heating element and the entire area of the corresponding dot position on the thermal paper becomes uniform.

[0007] The present invention is directed to solving these technical problems and an object of the invention is to provide a control method and apparatus for a heating element of a thermal head capable of printing two colors and applying thermal history control while featuring a simple circuit configuration.

[0008] This object is achieved wit a method as claimed in claim 1 and an apparatus as claimed in claim 6. Preferred embodiments of the invention are subject-matter of the dependent claims.

[0009] To the first color that requires the thermal paper to be exposed to the higher temperature, the present invention separately applies first and second energizing stages to assure the heat output required to produce the first color, actually printing the same dot twice. A sharp, clear first color print image can thus be achieved.

[0010] Preferably, the pause made between the two energizing stages is a time interval sufficiently long for the heat resulting from the first energizing stage to substantially uniformly expose the entire area of the respective dot position on the thermal paper to a temperature equal to or higher than that required for the first color. Thus the temperature of a respective heating elements distributes substantially uniformly to the entire dot position and a sharp, clear print image can be achieved.

[0011] Other objects and attainments together with a fuller understanding of the invention will become apparent and appreciated by referring to the following description of a preferred embodiment taken in conjunction with the accompanying drawings.

Fig. 1 is a block diagram showing the basic configuration of a control apparatus according to an embodiment of the invention for controlling the thermal head of a printer;

Fig. 2 is a block diagram showing the basic configuration of a thermal head to be controlled by the control apparatus of Fig. 1;

Fig. 3 shows the width ratio of strobe pulses generated in the control apparatus;

Fig. 4 and Fig. 5 are flow charts illustrating a method according to an embodiment of the invention for controlling the thermal head of a printer, the method being executed by the control apparatus of Fig. 1;

Fig. 6 is a timing chart showing the relative timing of various signals generated in the control apparatus;

Fig. 7 shows one example of print data used to facilitate an understanding of the invention;

Fig. 8 shows typical temperature versus time characteristics in accordance with the invention of a heating element (solid line) and of the thermal paper (dotted line); and

Fig. 9 illustrates the use of strobe pulses I to IV to implement a thermal history control in the control apparatus of Fig. 1.

[0012] Fig. 1 shows an embodiment of a control apparatus 30 used to control a thermal head 10 and a paper feed motor 2 of a thermal printer.

[0013] As shown in Fig. 2, the thermal head 10 has a heating unit 11 with a plurality of independently drivable heating elements arranged in a line. This heating unit 11 forms a desired dot pattern on thermal paper in conjunction with a relative movement between the thermal paper and the thermal head. In the embodiment shown, such relative movement is caused by a paper feed motor 2. A drive circuit 12 is electrically connected to each heating element of the heating unit 11. The thermal head 10 has a shift register 13 and a latch register 14 that will be further described in detail below.

[0014] Two types of thermal paper can be used with this thermal printer, that is, monochrome thermal paper that produces only one color in response to applied heat, and two-color thermal paper that produces different colors depending on how much heat is applied, more particularly, to what temperature it is exposed. There are two types of two-color thermal paper: (1) so-called "additive" paper that produces black as a first color when it is exposed to a relatively high temperature and produces red, blue or another color as the second color when it is exposed to a relatively low temperature, and (2) so-called "subtractive" paper that produces red, blue or another color as the first color when it is exposed to a relatively high temperature and produces black as the second color when it is exposed to a relatively low temperature. The present invention can use either additive or subtractive thermal paper, and is described below using a red additive color type two-color thermal paper that produces a first color (black in this embodiment) when a relatively high heat level is applied and produces a second color (red in this embodiment) when a relatively low heat level is applied.

[0015] Each heating element is either not energized, when no dot is to be formed, or is energized by the corresponding drive circuit 12 to produce an amount of heat suitable to form a dot of either the first color or the second color on the thermal paper.

[0016] The thermal head control apparatus 30 has a print data processing unit 40 and a drive control circuit 50 electrically connected thereto. The print data processing unit 40 has a CPU 41, a ROM (not shown in the figure) for storing a control program, for example, first line buffer 43, a second line buffer 44, a RAM 42 in which specific areas are reserved as a first image buffer 46 and a second image buffer 47, and a selector 45. All or part of RAM 42 can alternatively be integrated in CPU 41.

[0017] The control program includes a first signal processing function and a second signal processing function for separating first and second color print data intermixed in a user-specified print data stream. The print data stream represents the dot pattern desired to be printed and includes for each dot position in the dot pattern information indicating whether or not a dot is to be printed and, if a dot is to be printed, whether it is to be printed in the first or the second color. The first signal processing function receives the print data stream, extracts print data H from the print data stream and stores the extracted print data H in the first image buffer 46. The second signal processing function receives the print data stream, extracts print data L from the print data stream and stores the extracted print data L in the second image buffer 47. Extracting print data H means generating, from the print data stream, a bit stream including one bit for each dot position of the dot pattern to be printed, with the bits corresponding to dot positions at which a dot is to be printed in the first color being 1 and all other bits being 0. In the same way, extracting print data L means generating, from the print data stream, another bit stream also including one bit for each dot position of the dot pattern to be printed, with the bits corresponding to dot positions at which a dot is to be printed in the second color being 1 and all other bits being 0. The terms "print data H" and "print data L" as used in this text refer to these bit streams or respective parts thereof. The term "print data H and L" refers to the OR combination (logic sum) of print data H and print data L as generated by the OR gate shown at the input to second line buffer 44 in Fig. 1. Further details of the first and second signal processing functions are not critical for the present invention and are neither shown in the drawing nor described, therefore.

[0018] The first line buffer 43 is a memory area for temporarily storing one line of the print data H stored in the first image buffer 46 which contains plural lines of print data H. The second line buffer 44 is a memory area for temporarily storing the logical sum of print data H and print data L for one line from the first and second image buffers. The content of first image buffer 46 is transferred, one line at a time, to the first line buffer 43, and the logical sum of print data from the first image buffer 46 and second image buffer 47 is transferred, one line at a time, to the second line buffer 44 under the control of the control program. The following operations are also performed under the control of that control program.

[0019] The selector 45 alternatively connects the first or the second line buffer 43, 44 to the drive control circuit 50 in order to selectively send the content from the first or the second line buffer 43, 44 to the drive control circuit 50.

[0020] The drive control circuit 50 includes a print signal transmission circuit 51, a control selector 54, a synchronization clock output circuit 55, an energizing output circuit 56, and an energizing timer 57.

[0021] The print signal transmission circuit 51 sends the content of first and second line buffers 43, 44 selectively modified according to thermal history to the thermal head 10, has a print buffer 52 and a history buffer 53, and is connected to selector 45.

[0022] The print signal transmission circuit 51 overwrites current data in print buffer 52 with the print data transmitted via selector 45 after transferring the current data in the print buffer 52 to the history buffer 53. History control in this embodiment is a "first generation history" control, i.e., a method whereby the history data for a current driven dot is based on the presence of immediately preceding print data.

[0023] The output terminal of the print buffer 52 is connected to one input terminal of the control selector 54, and is also connected to one input terminal of an AND gate. The output terminal of the history buffer 53 is connected to an inverted second input terminal of the AND gate, whose output terminal is connected to the other input terminal of control selector 54.

[0024] The control selector 54 is in turn connected to the shift register 13 of thermal head 10 so that it can write to the shift register 13 either the print data from print buffer 52 or the result of logic operations on the print data in print buffer 52 and the data in history buffer 53, that is, the modified print data involving the thermal history control.

[0025] The synchronization clock output circuit 55 outputs a synchronization clock signal CLK for writing the print data to the shift register 13. The print data or the modified print data is written to the shift register 13 based on the synchronization clock signal as print data indicating the on/off states of the respective heating elements.

[0026] The energizing output circuit 56 generates a latch signal /LAT and strobe signals /STn (/ST1 TO / ST4) synchronized to a timing indicated by energizing timer 57. The latch signal is applied to the latch register 14 of thermal head 10. The strobe signals are applied to the drive circuits 12 through respective NOT gates. The drive circuits 12 are each shown to be a NAND gate having one input terminal connected to a corresponding output terminal of the latch register 14 and another input terminal connected to a corresponding one of the NOT gates. Strobe signals /ST1 to /ST4 differ from each other only by being phase-shifted preferably such that there is no overlap between any two of these signals. The purpose of separating the strobe signal into four phase-shifted signals applied to different heating elements is to keep the peak load on the system power supply low enough to avoid voltage fluctuations due to a greatly varying load. As shown in Fig. 2, each of the four phase-shifted strobe signals controls a respective pair of heating elements, so that if all eight heating elements included in the illustrated heating unit 11 were to be energized for a particular line, they would be energized sequentially in four phases, two at a time.

[0027] The latch register 14 receives the content of the shift register 13 in response to the latch signal. The print data (or modified print data) thus stored in the latch register 14 determine the on/off state of respective heating elements in the heating unit based on whether a respective bit of the print data is a 1 (print) or a 0 (do not print).

[0028] Based on a energizing pulse width table stored in RAM 42 of print data processing unit 40, each of the four the strobe pulses /ST1 to ST4 is generated as a sequence of first strobe pulses I and II with a specific pulse width and second strobe pulses III and IV following the first strobe pulses after a predetermined pause. Hence, each of the four strobe signals is subdivided into four sequential phases, of which phases I and II are virtually continuous, phases III and IV are also virtually continuous, but phases II and III are not continuous.

[0029] It should be noted that, as shown in Fig. 3 and Fig. 8, the ratio between the sum the widths of first strobe pulses I and II and the sum of the widths of second strobe pulses III and IV is preferably (I + II) ≥ (II + III) due to the relationship between the temperatures t1 and t2 required to produce the first and second colors, respectively, and the need to apply a high heat level in the first stage in order to quickly heat the heating elements of the thermal head 10.

[0030] Furthermore, the width ratio of strobe pulse I to strobe pulse II is preferably I s II considering the need to adjust heat output with consideration for the thermal history of the heating elements in the thermal head 10.

[0031] This embodiment, however, does not apply thermal history control to strobe pulse III. While described in further detail below, this is basically because the pause is provided between strobe pulse II and strobe pulse III when printing the first color and it is not necessary to consider thermal history for strobe pulse III if it is considered with strobe pulse IV. For printing the second color it is not necessary to consider thermal history because strobe pulses I and II are not used then.

[0032] The width ratio of strobe pulses I:II:III:IV in the present embodiment is therefore 0.1 : 0.55 : 0.05 : 0.3.

[0033] The control process carried out by the control apparatus of this embodiment of the invention is described next below with reference to Figs. 4 to 9.

[0034] Referring to Fig. 4, when the print data processing unit 40 of the control apparatus 30 receives a print command in step S1, step S2 determines if the print mode is set to the "two-color" mode or the "monochrome" mode. The print mode could be set by DIP switches, for example.

[0035] If the two-color mode is set, control steps to step S3. If the monochrome mode is set, control branches to the routine shown in Fig. 5.

[0036] In step S3 the CPU 41 extracts the first color print data H from the print data stream and temporarily stores them in the first image buffer 46, and extracts the second color print data L from the print data stream to temporarily store them in the second image buffer 47 as explained above. Fig. 7 shows an example in which lines n and n+1 of the print data stream, successive in the paper feed direction, are to be printed (note that only data for heating elements (m-2) to (m+4) of heating unit 11 are shown). Line n is represented by print data 0 0 H, H, L, L 0 and line n+1 is represented by print data 0 0 H, L, H, L 0. "0" means no dot is to be printed by the respective heating element whereas H and L mean that a dot is to be printed in the first or the second color, respectively. H and L correspond to a "1" bit in the first and the second image buffer, respectively, and are indicated by a black dot in Fig. 7. 0 corresponds to a "0" bit in both image buffers and is represented by a blank space in Fig. 7. The following description assumes printing as indicated in Fig. 7.

[0037] In step S4 the CPU 41 sends the print data H for line n from first image buffer 46 to the first line buffer 43, and sends the print data H and L (i.e., the logical sum of print data H for line n in image buffer 46 and print data L for line n in image buffer 47) to the second line buffer 44.

[0038] After connecting first line buffer 43 to drive control circuit 50 by means of selector 45 in step S5, the print data H of line n from first line buffer 43 is sent to the print buffer 52. Simultaneously to transferring data from first line buffer 43 to print buffer 52, the current data in print buffer 52 is transferred to history buffer 53 for use as history data.

[0039] Then in step S6 control selector 54 is caused by a command from print data processing unit 40 to apply the modified print data H (combined from the print data H '0011000' in print buffer 52 and the history data '0000000' in history buffer 53) as print signal I to shift register 13 of thermal head 10. The modified print data H in this case is '0011000' for heating elements m-2 to m+4 because all bits in line n-1 are 0 and in print data H of line n the bits for heating elements m and m+1 are 1, the other bits being 0. When the transfer is completed, a latch pulse I of the latch signal /LAT is applied to latch register 14 of thermal head 10 (step S7). This causes the print signal I in shift register 13 to be loaded into the latch register 14.

[0040] In step S8 paper feed motor 2 is driven to start feeding the thermal paper based on a command from print data processing unit 40, and control advances to step S9 based on a control signal from paper feed motor 2.

[0041] The control selector 54 is then driven to select and pass as print signal II the print data H from print buffer 52 to shift register 13 of thermal head 10 based on a command from print data processing unit 40 (step S9).

[0042] At the same time, heating elements m and m+1 of thermal head 10 are energized according to the print signal I stored in the latch register 14 (step S10). After latch pulse I of the latch signal has been applied the content of the shift register 13 can be changed without influencing that in the latch register 14, so the heating elements can be energized based on the data latched in the latch register while print signal II is being transferred to shift register 13. The heating elements are controlled by the print signal I for the duration of strobe pulse I, and an amount of heat determined by the width of strobe pulse I is applied to the heating elements whose corresponding bit in print signal I is 1 (heating elements m and m+1 in this example). At step S12 second line buffer 44 and drive control circuit 50 are connected by the selector 45, and the print data H and L of line n from second line buffer 44 is thus transferred to the print buffer 52 (see Fig. 1 and Fig. 7).

[0043] In step S11 print signal II in the shift register 13 is loaded into the latch register 14 based on a latch pulse II of latch signal /LAT. Subsequently, in step S13 print signal II is applied to the heating elements of the thermal head 10 for the duration of strobe pulse II of strobe signals /ST1 TO ST4. With respect to the example shown this means that heating elements m and m+1 are energized, and the amount of heat is determined by the width of strobe pulse II. As will be appreciated, the amount of heat generated by a heating element does not only depend on the width of the respective strobe pulse but, of course, also on the height of the current flowing through the heating element during that time. In the present text, the height of the current is considered to be always the same, is thus regarded merely a constant of proportionality and is not further considered, therefore.

[0044] In step S12, executed in parallel to step S13, the print data H in print buffer 52 (that is, the first line buffer data) is loaded into the history buffer 53 for use as history data, while second line buffer 44 and drive control circuit 50 are connected by selector 45, and the print data H and L for line n from second line buffer 44 is transferred to the print buffer 52.

[0045] Control selector 54 then sends the modified print data H and L (combined from the print data H and L '0011110' in print buffer 52 and the history data '0011000' in history buffer 53) as a print signal III to shift register 13 of thermal head 10 based on a command from print data processing unit 40 (step S14). In this example, only the data for heating elements m+2 and m+3 among the modified print data H and L are 1). It is to be noted that "thermal history control" as represented by print signal III is different from "thermal history control" represented by print signal I although both signals are generated by the same circuitry. "Thermal history control" as applied to print signal I is an "inter-line" thermal history control" and corresponds to what is typically understood by this term, namely to adapt the amount of heat generated by a certain heating element depending on whether the same heating element was energized in the preceding print line. "Thermal history control" as applied to print signal III, on the other hand, is an "intra-line" thermal history control that prevents, as illustrated in Fig. 9, any heating element that is to print a dot in the first color to be energized during strobe pulse III. On the other hand, any heating element that is to print a dot in the second color is energized during strobe pulse III irrespective of the thermal history of that heating element.

[0046] Based on a latch pulse III of the latch signal /LAT, print signal III is loaded from shift register 13 into latch register 14 (S15). Subsequently, in step S17 print signal III is applied to the heating elements of thermal head 10 for the duration of strobe pulse III (which means heating elements m+2 and m+3 are energized in the example), while at the same time control selector 54 is driven by a command from print data processing unit 40 to transfer as print signal IV the print data H and L for line n in print buffer 52 to shift register 13 of thermal head 10 (step S16).

[0047] Based on a latch pulse IV of the latch signal /LAT in steps S18, print signal IV in shift register 13 is loaded into latch register 14. In step S19 print signal IV is applied to the heating elements of thermal head 10 during strobe pulse IV. In the example, this results in heating elements m to m+3 being energized.

[0048] As shown in Fig. 8, when a heating element is energized during strobe pulses I and II, i.e., in a first energizing stage, the temperature to which the thermal paper is exposed at the position in contact with that heating element exceeds the temperature t1 causing the thermal paper to produce the first color (threshold temperature t1 for the first color) thereby producing a dot of the first color (black in this embodiment) at the corresponding dot position.

[0049] The total width of strobe pulses I and II is longer and, thus, the amount of heat generated is higher, than those of strobe pulses III and IV. Therefore, a heating element energized during strobe pulses I and II is raised quickly to a first peak temperature T1.

[0050] If then, after a pause of a predetermined time period and no energization during strobe pulse III (Fig. 9(c)), the same heating element is again energized, in a second energizing stage, during strobe pulse IV, it is heated to a second peak temperature T2 substantially equal to the first peak temperature T1.

[0051] In accordance with the present invention, each heating element of the thermal head 10 that is to print a dot in the first color, i.e., the color requiring the higher temperature, actually prints twice to the same dot position on the thermal paper with a decrease of temperature between the end of the first energizing stage (first printing) and the begin of the second energizing stage (second printing). The pause between the first and the second energizing stages is selected to provide enough time for the temperature to distribute substantially uniformly across the entire surface of the respective heating element and expose the dot position of the thermal paper to such uniform temperature distribution at a level exceeding the threshold temperature t1 for the first color. Thus, the phenomenon of a rim of the second color appearing around the edges of first color dot is prevented or at least reduced; and a print image with a clear representation of the first color can be achieved. Furthermore, by setting the amount of heat generated by the first energizing stage higher than that generated by the second energizing stage, a respective dot on the thermal paper is first printed with a dark color and then reprinted with a lighter color, thereby clearly defining the outside edges of the print image.

[0052] If the CPU 41 determines in step S20 that print data H, L remains in first and second image buffers 46, 47, it returns to step S4 and repeats steps S4 to S19 for the next line n+1. If no more print data H, L is found in first and second image buffers 46, 47, the CPU 41 ends the two-color mode printing process. It should be noted that the flow chart shows returning to step S4 from step S20 after completing step S19 when print data remains in the image buffers. In fact, energizing the heating elements based on print signal IV for the duration of strobe pulse IV (step S19) can be performed simultaneously with the execution of steps S4 to step S6. Therefore, in practice it is preferable to execute step S19 while steps S20 and S4, S5, S6 are being executing.

[0053] The process as it applies to line n+1 is described below primarily with reference to the differences from the process applied to line n.

[0054] In step S4 the CPU 41 sends the print data H for line n+1 from first image buffer 46 to the first line buffer 43, and sends the print data H and L for line n+1 to the second line buffer 44 as was the case in the context of line n described above.

[0055] In step S5, the print data in print buffer 52 for the previous printing operation (i.e., the print data H and L for line n) is loaded into the history buffer 53. At the same time, the print data H for line n+1 is transferred from first line buffer 43 to print buffer 52.

[0056] Then in step S6 control selector 54 is caused by a command from print data processing unit 40 to apply the modified print data H (combined from the print data H '0010100' in print buffer 52 and the history data '0011110' in history buffer 53) as print signal I to shift register 13 of thermal head 10. The modified print data H in this case is '0000000', i.e., no heating element is to be energized.

[0057] Steps S7 and S8 are executed again and then, in step S9, the print data H '0010100' for line n+1 in print buffer 52 is transferred to the shift register 13, while at the same time step 10 is executed. Because all bits of print signal I for line n+1 are 0, no heating element is energized during strobe pulse I in step S10.

[0058] From this point on only steps relating to data transfer are described.

[0059] In step S12 the print data H and L '0011110' for line n+1 of second line buffer 44 is transferred to print buffer 52, after the data H '0010100' from print buffer 52 have been loaded into history buffer 53 for use as history data.

[0060] In step S14 the modified print data H and L for line n+1 '0010100' is transferred to the thermal head 10 shift register 13 as print signal III.

[0061] In step S16 the print data H and L for line n+1 '0011110' is transferred as print signal IV from print buffer 52 to shift register 13.

[0062] When, as with the data for line n+1, the first color is to be printed by a particular heating element and the same heating element printed a dot of either color in the preceding line, the amount of heat (proportional to pulse widths (I+II)) applied by the first energizing stage would be higher than it would be if the same heating element did not print a dot in the preceding line. This higher amount of heat is avoided by the thermal history control as applied to print signal I, more particularly, in such case the first energizing stage comprises energizing only during strobe pulse II and not during strobe pulse I with the width of strobe pulse I being chosen such that the amount of heat that would be applied during strobe pulse I is substantially equal to the amount of heat still remaining in the heating element from the preceding line. This "inter-line" thermal history control means that the respective heating element is not energized while strobe pulse I is applied but is energized while strobe pulse II is applied (Fig.9 (b)) to heat to first peak temperature T1 by means of this first energizing stage.

[0063] Fig. 9 illustrates the use of strobe pulses I to IV to implement a thermal history control in the control apparatus of Fig. 1 with reference to three cases (a) to (c). According to case (a), to print a dot in the second color, the corresponding heating element is energized during strobe pulses III and IV irrespective of the thermal history of that heating element. According to cases (b) and (c), to print a dot in the first color the corresponding heating element is energized during strobe pulses I, II and IV if the same heating element did not print in the preceding line (case (c)), otherwise the heating element is energized only during strobe pulses II and IV (case (b)).

[0064] If the print data processing unit 40 detects the monochrome mode in step S2, the process branches from step S2 to the routine shown in Fig. 5. Like steps Figs. 4 and 5 are denoted by like reference signs.

[0065] This case differs from the two-color print mode in that the print data only indicates whether a particular dot is to be printed or not without discriminating print colors, and the control process uses only first image buffer 46 and first line buffer 43. As will be understood, because only the first image buffer 46 and the first line buffer 43 are used in this mode, the routine of Fig. 5 equals that of Fig. 4 with the exception that step S12 and steps S14 to S19 in Fig. 4, i.e., those steps that process the data from the second image buffer 47 and the second line buffer 44, are skipped.

[0066] In embodiment explained above, first and second line buffers 43, 44 are reserved in RAM 42 of print data processing unit 40, and print data H for the first color and print data L for the second color are managed in print data processing unit 40 for transfer from the first and second line buffers 43, 44 to the drive control circuit 50. The drive control circuit 50 can be used as a circuit for thermal history control of monochrome printing to maintain constant temperature output from the heating elements of the thermal head 10 with consideration for thermal history, and the heat output necessary to produce the first color and heat output necessary to produce the second color can be separately controlled and produced at the appropriate heating elements of the thermal head 10.

[0067] It is possible to provide a control apparatus 30 featuring a simple circuit configuration and applying thermal history control for a thermal head 10 capable of printing two colors.

[0068] The invention uses the second energizing stage alone to print the second color.

[0069] Furthermore, the present invention makes it possible to change the settings of strobe pulses I and III according to the type of thermal paper because strobe pulses II and IV are the signals always used for print data H and strobe signals I and III are selected based on thermal history. Strobe pulse IV is similarly the signal required for print data L and strobe pulse III is selectable, making it also possible to change the value of strobe pulse III according to the type of thermal paper.

[0070] By setting the amount of heat generated by the first energizing stage higher than that generated by the second energizing stage, a dot on the thermal paper is first printed using a dark color and is printed a second time using a lighter color, thereby assuring a well-defined print image. It is also possible to rapidly heat the heating elements when printing to thermal paper while heating to the higher temperature level.

[0071] When only the second energizing stage is used for printing the color produced by the lower temperature level, the heating elements of the thermal head can cool down sufficiently during the period of the (unused) first energizing stage. It is therefore not necessary to apply thermal history control in this case.

[0072] In the second energizing stage, the heat output is required to produce the color emitted at the lower temperature level. A sharp, clear second color print image can thus be achieved.

[0073] Furthermore, the output temperature of the heating elements of a thermal head can be held constant with consideration for thermal history even when the drive control circuit is a circuit enabling thermal history control for monochrome printing, and the heat output required to produce the first color and the heat output required to produce the second color can be separately controlled and produced in the individual heating elements of the thermal head. It is therefore possible to provide a control apparatus featuring a simple circuit configuration and applying thermal history control for a thermal head capable of printing two colors.

[0074] Print data for controlling the first energizing stage can therefore be stored in a first memory area for print data H, and print data for the second energizing stage can be stored in a second memory area for print data H and L. Information relating to the heat output required to produce the first color can therefore be applied to the drive control circuit for the first and second energizing stage, and information relating to the heat output required to produce the second color can be applied to the drive control circuit for only the second energizing stage .

[0075] Yet further, heat output required to produce the first color can be controlled using the energizing pulse width determined by a plurality of first and second stage energizing commands.

[0076] Yet further, the present invention can appropriately change the energizing pulse width of the initial first stage energizing command, and make the pause of the predetermined time period, so that the temperature generated in the first energizing stage and second energizing stage is uniform for a particular heating element of the thermal head. A sharp, clear first color print image can thus be achieved.

[0077] Further preferably, the present invention can also appropriately change the energizing pulse width set by the initial second stage energizing command so that the temperature generated in the second energizing stage is uniform for a particular heating element of the thermal head. A sharp, clear second color print image can thus be achieved.

[0078] The present invention can also selectively energize the heating elements of the thermal head in order to achieve the basic heat output level required to produce the first and second colors, and to achieve the heat output required to produce the first and second colors with consideration for thermal history.

[0079] This invention allows implementing a thermal head printer using a monochrome printing drive circuit applying thermal history control to enable sharp, clear monochrome and two-color printing.

[0080] The invention may be summarized as follows:

(1) A thermal head control method for controlling different heat output levels by changing the amount of energizing applied to heating elements of a thermal head, comprising the steps of:

(a) energizing the heating elements in a first energizing stage and in a second energizing stage to produce a first color at a first heat output level; and

(b) providing a pause of predetermined duration between the first energizing stage and the second energizing stage.

(2) The method of (1), wherein: the pause of predetermined duration is sufficient to permit the second energizing stage to distribute the first heat output level substantially throughout the entire surface of the heating elements.

(3) The method of (1), wherein: the first energizing stage is greater than the second energizing stage.

(4) The method of (1), wherein: the heating elements are energized only in the second energizing stage to produce a second color at a second heat output level.

(5) The method of (4), wherein: the energizing in the second energizing stage is sufficient to produce said second color at a second heat output level.

(6) A thermal head control apparatus for controlling heat output from heating elements of the thermal head by changing the amount of energizing applied to each heating element in a thermal head having an array of multiple, independently drivable, heating elements, comprising:

a print data processing unit for processing a print data group that is information relating to the production of color at a specific heating element according to different heat output levels and contains both or either first color data based on a first heat output level and second color data based on a second heat output level lower than the first heat output level, the print data processing unit having:

a first command processing function for converting first color data to a first stage energizing command and a second stage energizing command,

a second command processing function for converting second color data to the second stage energizing command,

a first memory area for storing the first stage energizing command, and

a second memory area for recording the second stage energizing command, and

a selector for selectively outputting energizing commands from the first memory area and energizing commands from the second memory area; and

a drive control circuit having a first command storage area for storing energizing commands contained in the first memory area or second memory area, and a second command storage area for storing energizing commands contained in the first command storage area, and energizing a specific heating element by means of a energizing command based on a comparison between the first command storage area and second command storage area.

(7) The apparatus of (6), wherein the first command processing function of the print data processing unit extracts first color data from the print data group to a first working area and stores it to the first memory area, and the second command processing function extracts second color data from the print data group to a second working area and stores the result of a logic operation on the first working area and second

working area to the second memory area.

(8) The apparatus of (6), wherein the print data processing unit converts first stage energizing commands and second stage energizing commands to a plurality of energizing commands stored to the memory areas based on print data and the history of energizing the heating elements.

(9) The apparatus of (8), wherein the multiple first and second stage energizing commands are energizing pulses, and their energizing pulse width is determined according to the heat output required to produce the first color.

(10) The apparatus of (9), wherein the energizing pulse width of the multiple second stage energizing commands is determined according to the heat output required to produce the second color.

(11) The apparatus of (9), wherein the initial first stage energizing command is determined based on a relationship between heat output due to multiple second stage energizing commands and the cooling temperature of the thermal head heating element.

(12) The apparatus of (9), wherein the initial second stage energizing command is determined based on a relationship between heat output due to multiple first stage energizing commands and the cooling temperature of the thermal head heating element.

(13) The apparatus of (8), wherein the drive control circuit runs a last first stage energizing command or last second stage energizing command directly from the storing command storage area based on the print data, and runs energizing commands other than the last first stage energizing command or last second stage energizing command based on a NOT-AND operation between a command storage area stored based on print data and a previous-print-data command storage area.

(14) The apparatus of (8), wherein the drive control circuit comprises an energizing output circuit for outputting an N-th strobe signal at a specific timing for an N-th energizing command, where N is a positive integer.

(15) The apparatus of (8), wherein the control apparatus uses the drive control circuit for monochrome printing, and by using only the first stage energizing command prints one line using half the energizing commands used for two-color printing.

Claims

1. A method of controlling a heating element of a thermal head (10) for printing on thermal paper that generates a first color in response to heat at or above a first temperature (t1) and a second color in response to heat at or above a second temperature (t2) but below the first temperature (t1), comprising the steps of:

energizing the heating element, to print a dot in said first color, in a first energizing stage, making a pause of a predetermined time period and then energizing the heating element in a second energizing stage.

2. The method of claim 1, wherein said pause is set to a time interval sufficient for the temperature distribution to become substantially uniform throughout the entire surface of the heating element.

3. The method of claim 1 or 2, wherein the amount of heat generated in the first energizing stage is greater than that generated in the second energizing stage.

4. The method of claim 1, 2 or 3 further comprising energizing the heating element, to print a dot in said second color, only in the second energizing stage.

5. The method of any one of the preceding claims, wherein at least said first energizing stage is subdivided into at least two sections, during the first of which sections the heating element being energized or not depending on thermal history control.

6. A control apparatus for controlling heating elements of a thermal head (10) for printing on thermal paper that generates a first color in response to heat at or above a first temperature (t1) and a second color in response to heat at or above a second temperature (t2) but below the first temperature (t1), comprising:

receiving means for receiving a data stream of print data representing a dot pattern to be printed and indicating for each dot position in the dot pattern whether a dot is to printed or the dot position to remain blank, and, if a dot is to be printed, whether it is to be printed in said first or said second color,
a print data processing unit (40) for converting print data indicating a dot is to be printed in said first color into both first print data and second print data, and for converting print data indicating a dot is to be printed in said second color into second print data,
a first memory area (43) for storing the first print data,

a second memory area (44) for storing both the first print data and the second print data,

selector means (45) for selectively outputting first print data from the first memory area (43) or first and second print data from the second memory area (44); and

a drive control circuit (50) having a first storage area (52) for storing the print data output by said selector means (45), and a second storage area (53) adapted to receive the print data contained in the first storage area (52) prior to those print data being overwritten by print data newly output by said selector means (45), the drive control circuit (50) being adapted to generate energizing commands to selectively energize the heating elements based on a comparison between print data in the first storage area (52) and the print data in the second storage area (53).

7. The apparatus of claim 6, wherein the print data processing unit (40) comprises first processing means for generating, from the first data stream, a first data sequence of print data indicating for each dot position in said dot pattern whether or not a dot is to be printed in said first color, second processing means for generating, from the first data stream, a second data sequence of print data indicating for each dot position in said dot pattern whether or not a dot is to be printed in said second color, a third memory area (46) for storing the first data sequence, a fourth memory area (47) for storing the second data sequence and means for storing the print data from said third memory area (46) as said first print data in said first memory area (43) and the result of a logic operation on print data in the third and fourth memory areas as said first and second print data in said second memory area (44).

8. The apparatus of claim 6 or 7, wherein said drive control circuit (50) converts the first print data and the second print data into a plurality of first stage energizing commands and second stage energizing commands based on the print data stored in said first storage area (52) and the print data stored in said second storage area (53) and representing the history of energizing the heating elements.

9. The apparatus of claim 8, wherein the plurality of first and second stage energizing commands are energizing pulses, the total pulse width of which being set so that a heating element energized by these first and second stage energizing pulses generates an amount of heat sufficient to produce the first color.

10. The apparatus of claim 9, wherein the total pulse width of a plurality of second stage energizing pulses is set so that a heating element energized by these second stage energizing pulses generates an amount of heat sufficient to produce the second color.

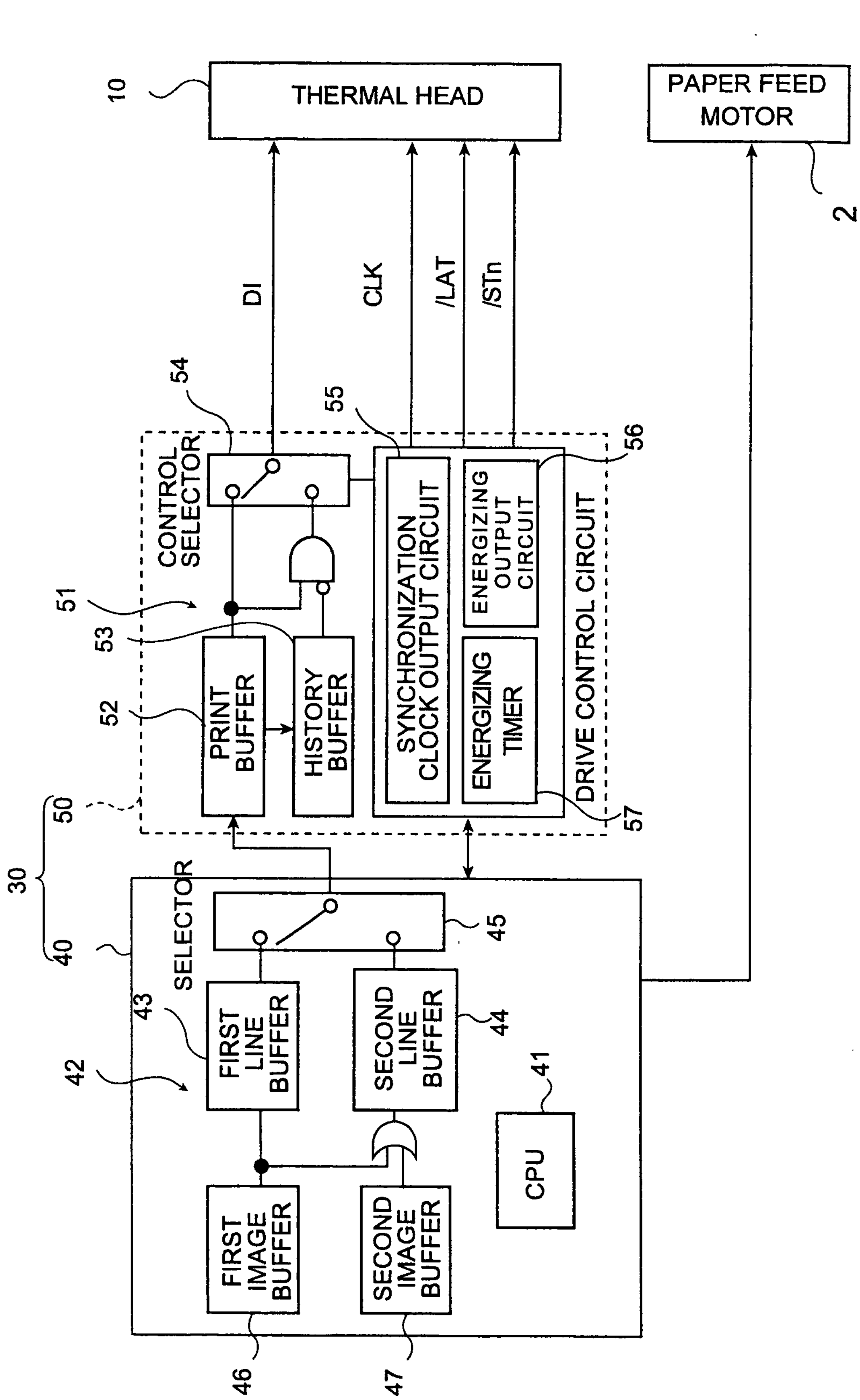
11. The apparatus of claim 9 or 10, wherein the pulse width of an initial first stage energizing pulse is determined based on the relationship between heat output in response to the second stage energizing pulses and the rate of temperature decrease of a non-energized heating element.

12. The apparatus of any one of claims 9 to 11, wherein an initial second stage energizing pulse is determined based on the relationship between heat output in response to at least the last first stage energizing pulse and the rate of temperature decrease of a non-energized heating element.

13. The apparatus of any one of claims 8 to 12, wherein the drive control circuit (50) generates a last first stage energizing pulse or a last second stage energizing pulse depending on the print data stored in said first storage area (52), and generates first stage energizing pulses other than the last first stage energizing pulse of a plurality of first stage energizing pulses and second stage energizing pulses other than the last second stage energizing pulse of a plurality of second stage energizing pulses based on a NOT-AND operation between the print data contained in said first (52) and those contained in said second storage area (53).

14. The apparatus of any one of claims 9 to 13, wherein the number of first stage energizing pulses and/or that of second stage energizing pulses is two.

15. The apparatus of any one of claims 8, 9, 11, or 13, adapted to use the same drive control circuit (50) for monochrome printing by processing only the print data from said first memory area (43) and generating only half the energizing commands used for two-color printing.



10
THERMAL HEAD
PAPER FEED MOTOR
2
DI
CLK
/LAT
/STn
54
55
56
CONTROL SELECTOR
51
53
52
PRINT BUFFER
HISTORY BUFFER
SYNCHRONIZATION CLOCK OUTPUT CIRCUIT
ENERGIZING OUTPUT CIRCUIT
ENERGIZING TIMER
DRIVE CONTROL CIRCUIT
57
30
50
40
SELECTOR
45
43
42
FIRST LINE BUFFER
SECOND LINE BUFFER
44
41
CPU
FIRST IMAGE BUFFER
SECOND IMAGE BUFFER
46
47

FIG. 1

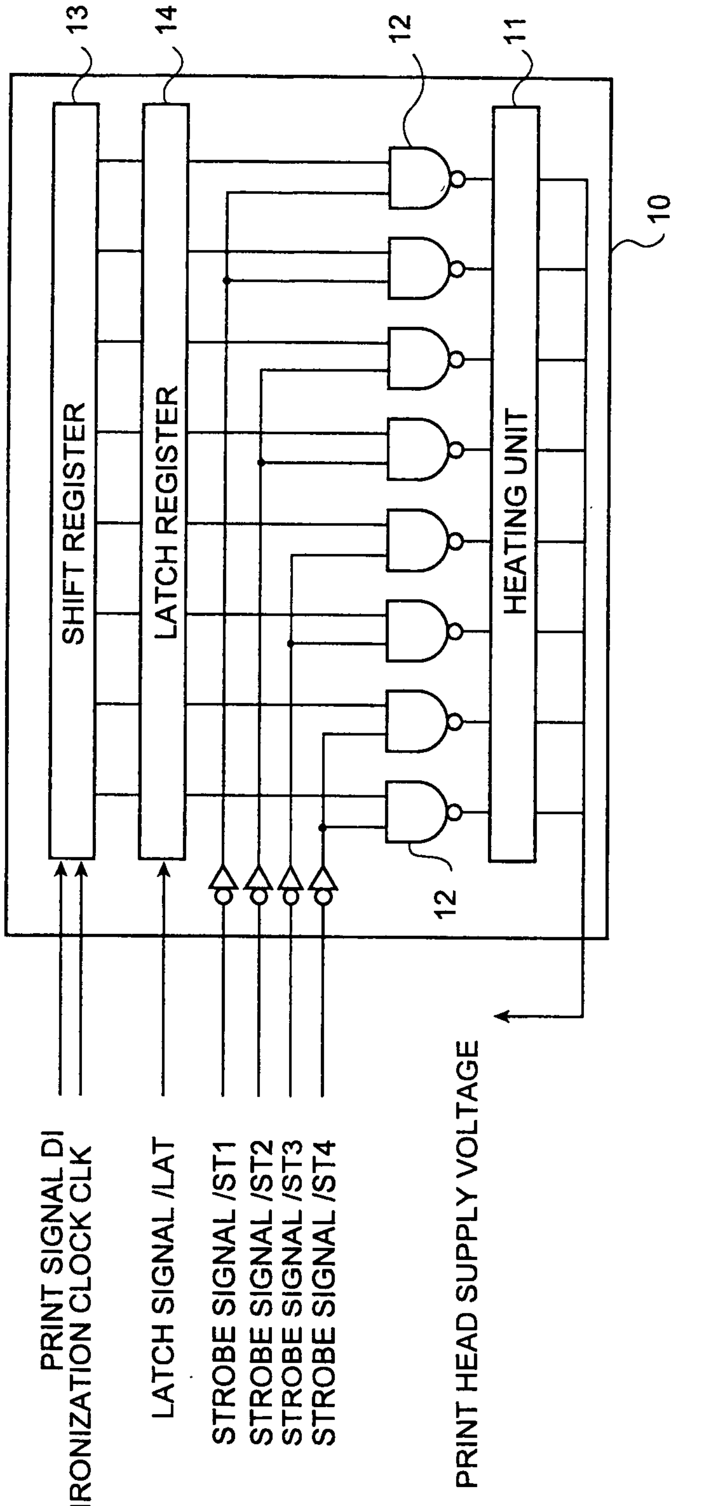

SHIFT REGISTER
LATCH REGISTER
HEATING UNIT
13
14
12
11
10
12
PRINT SIGNAL DI
SYNCHRONIZATION CLOCK CLK
LATCH SIGNAL /LAT
STROBE SIGNAL /ST1
STROBE SIGNAL /ST2
STROBE SIGNAL /ST3
STROBE SIGNAL /ST4
PRINT HEAD SUPPLY VOLTAGE

FIG. 2

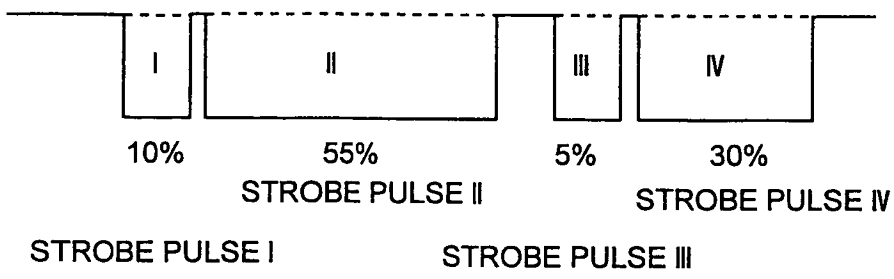

I
II
III
IV
10%
55%
5%
30%
STROBE PULSE II
STROBE PULSE IV
STROBE PULSE I
STROBE PULSE III

FIG. 3

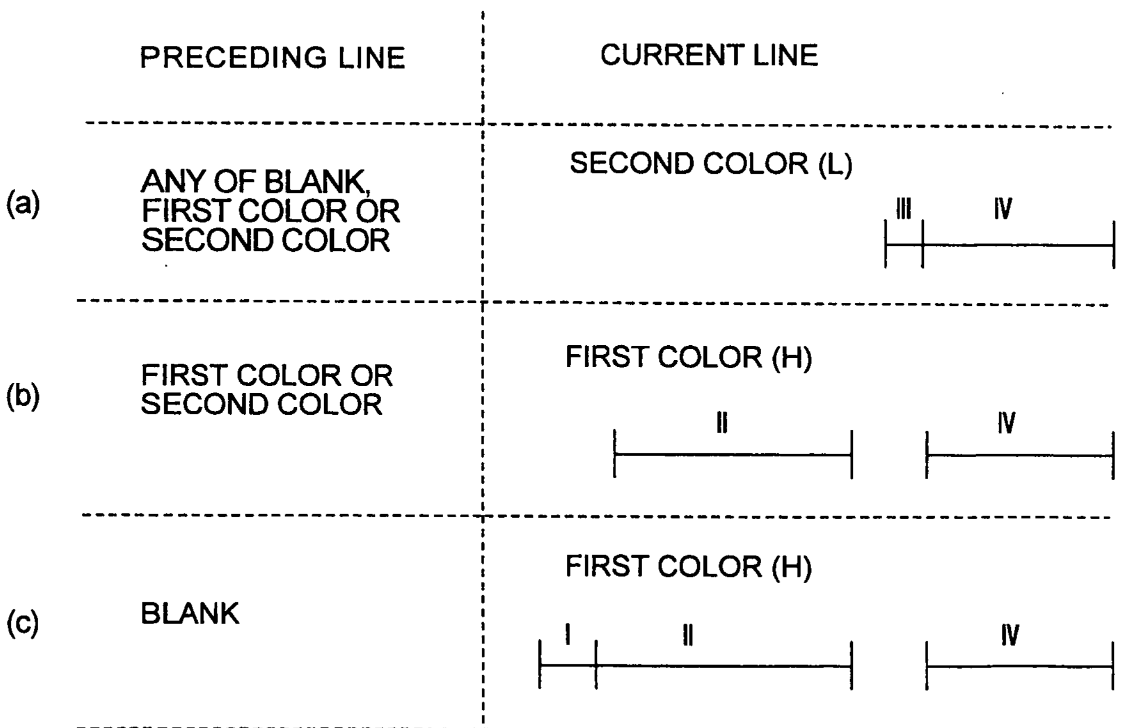

PRECEDING LINE
CURRENT LINE
(a)
ANY OF BLANK, FIRST COLOR OR SECOND COLOR
SECOND COLOR (L)
III
IV
(b)
FIRST COLOR OR SECOND COLOR
FIRST COLOR (H)
II
IV
(c)
BLANK
FIRST COLOR (H)
I
II
IV

FIG. 9

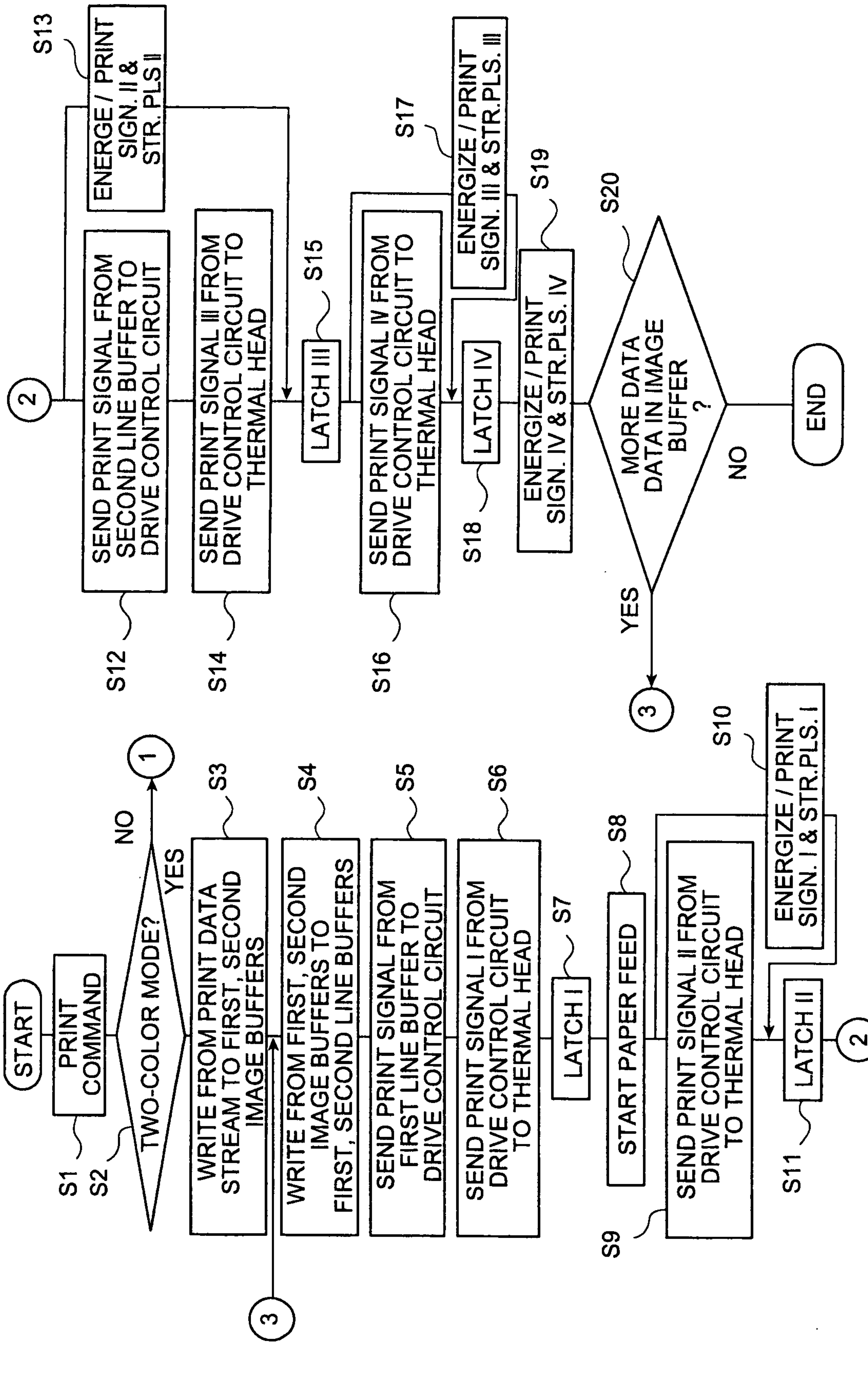

START
PRINT COMMAND
S1
TWO-COLOR MODE?
S2
NO
YES
1
WRITE FROM PRINT DATA STREAM TO FIRST, SECOND IMAGE BUFFERS
S3
WRITE FROM FIRST, SECOND IMAGE BUFFERS TO FIRST, SECOND LINE BUFFERS
S4
SEND PRINT SIGNAL FROM FIRST LINE BUFFER TO DRIVE CONTROL CIRCUIT
S5
SEND PRINT SIGNAL I FROM DRIVE CONTROL CIRCUIT TO THERMAL HEAD
S6
LATCH I
S7
START PAPER FEED
S8
SEND PRINT SIGNAL II FROM DRIVE CONTROL CIRCUIT TO THERMAL HEAD
S9
ENERGIZE / PRINT SIGN. I & STR.PLS. I
S10
LATCH II
S11
2
3
SEND PRINT SIGNAL FROM SECOND LINE BUFFER TO DRIVE CONTROL CIRCUIT
S12
ENERGE / PRINT SIGN. II & STR. PLS II
S13
SEND PRINT SIGNAL III FROM DRIVE CONTROL CIRCUIT TO THERMAL HEAD
S14
LATCH III
S15
SEND PRINT SIGNAL IV FROM DRIVE CONTROL CIRCUIT TO THERMAL HEAD
S16
ENERGIZE / PRINT SIGN. III & STR.PLS. III
S17
LATCH IV
S18
ENERGIZE / PRINT SIGN. IV & STR.PLS. IV
S19
MORE DATA DATA IN IMAGE BUFFER ?
S20
YES
NO
END

FIG. 4

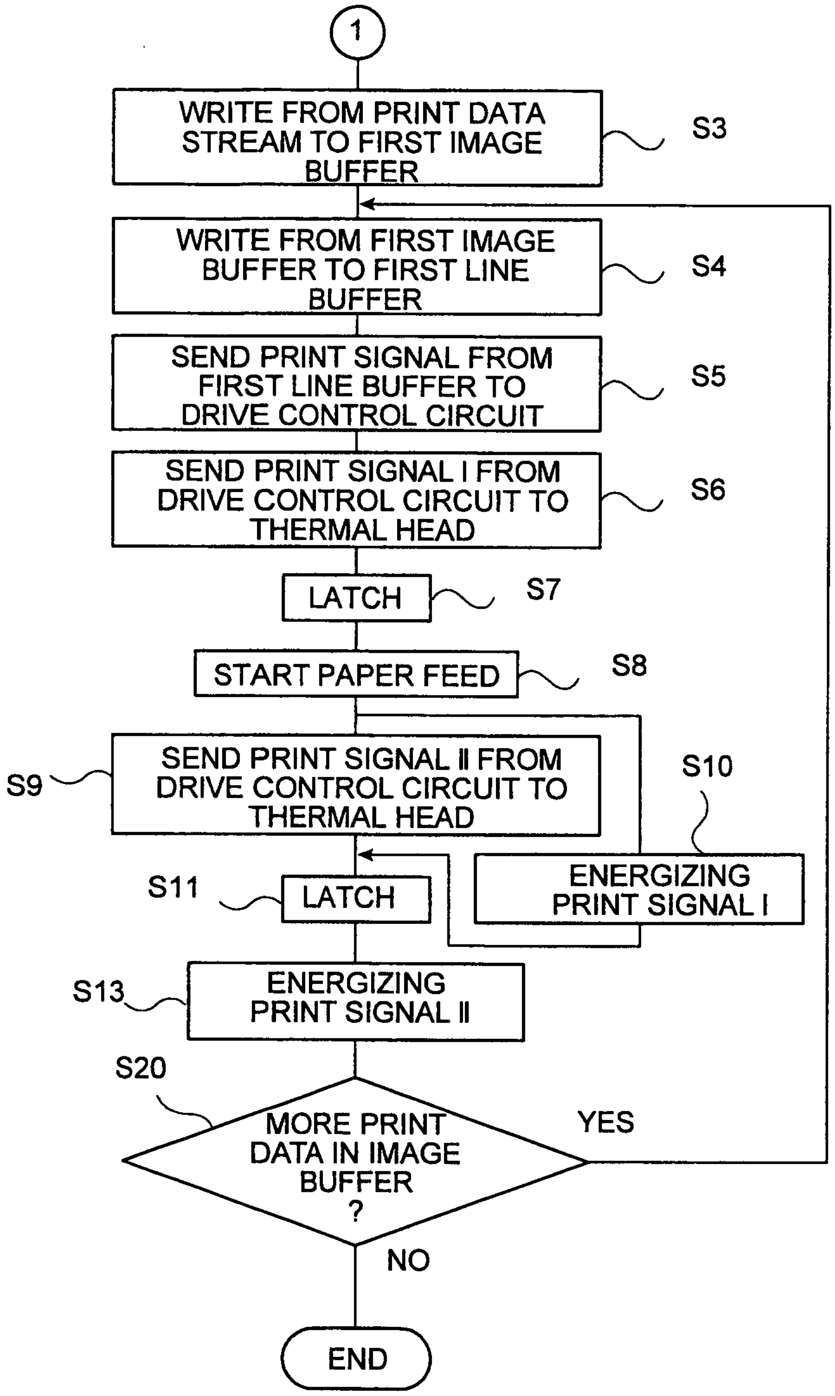

1
WRITE FROM PRINT DATA STREAM TO FIRST IMAGE BUFFER
S3
WRITE FROM FIRST IMAGE BUFFER TO FIRST LINE BUFFER
S4
SEND PRINT SIGNAL FROM FIRST LINE BUFFER TO DRIVE CONTROL CIRCUIT
S5
SEND PRINT SIGNAL I FROM DRIVE CONTROL CIRCUIT TO THERMAL HEAD
S6
LATCH
S7
START PAPER FEED
S8
SEND PRINT SIGNAL II FROM DRIVE CONTROL CIRCUIT TO THERMAL HEAD
S9
S10
ENERGIZING PRINT SIGNAL I
LATCH
S11
ENERGIZING PRINT SIGNAL II
S13
S20
MORE PRINT DATA IN IMAGE BUFFER ?
YES
NO
END

FIG. 5

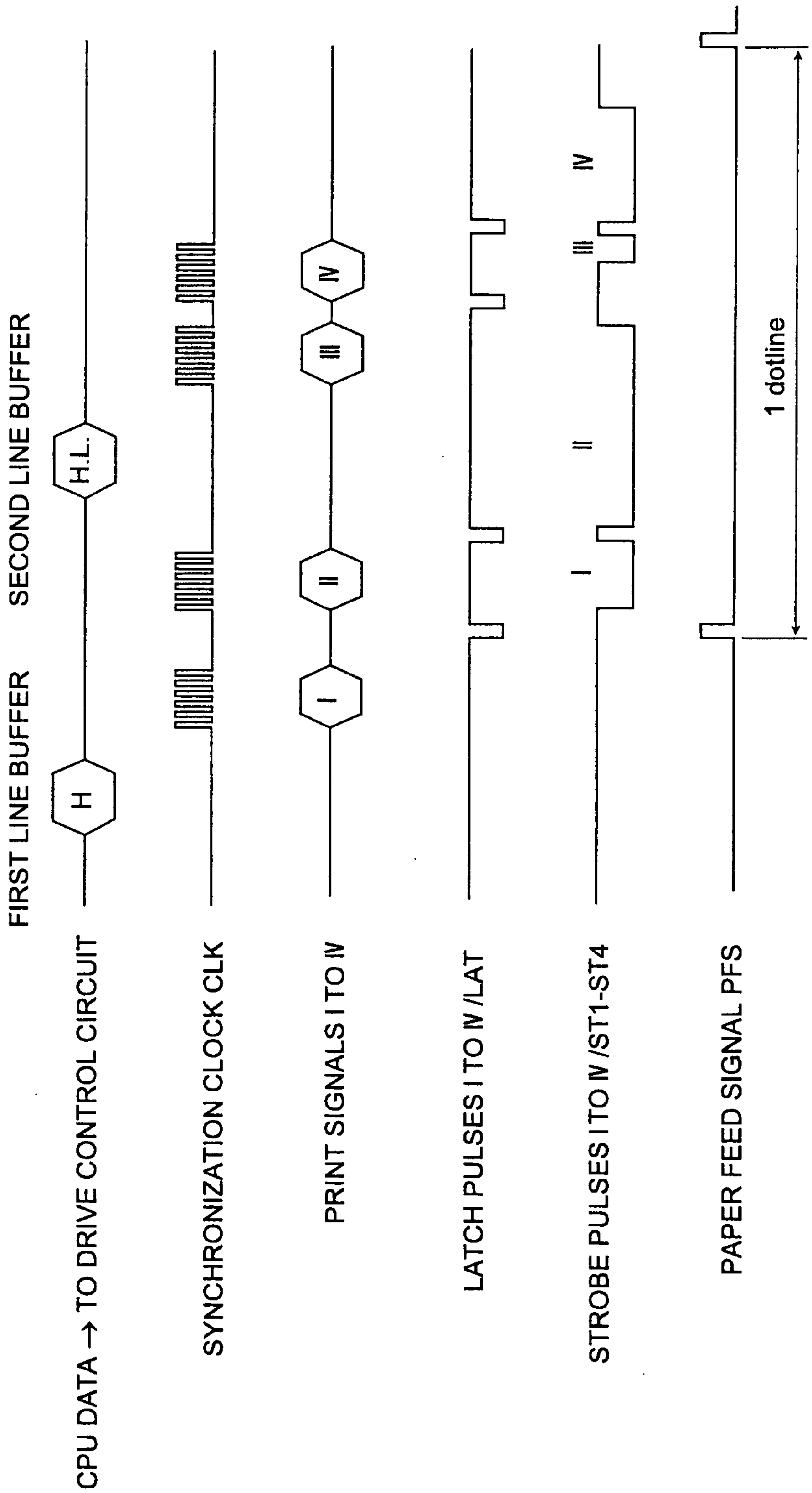

FIRST LINE BUFFER
SECOND LINE BUFFER
H
H.L.
CPU DATA → TO DRIVE CONTROL CIRCUIT
SYNCHRONIZATION CLOCK CLK
PRINT SIGNALS I TO IV
I
II
III
IV
LATCH PULSES I TO IV /LAT
STROBE PULSES I TO IV /ST1-ST4
PAPER FEED SIGNAL PFS
1 dotline

FIG. 6

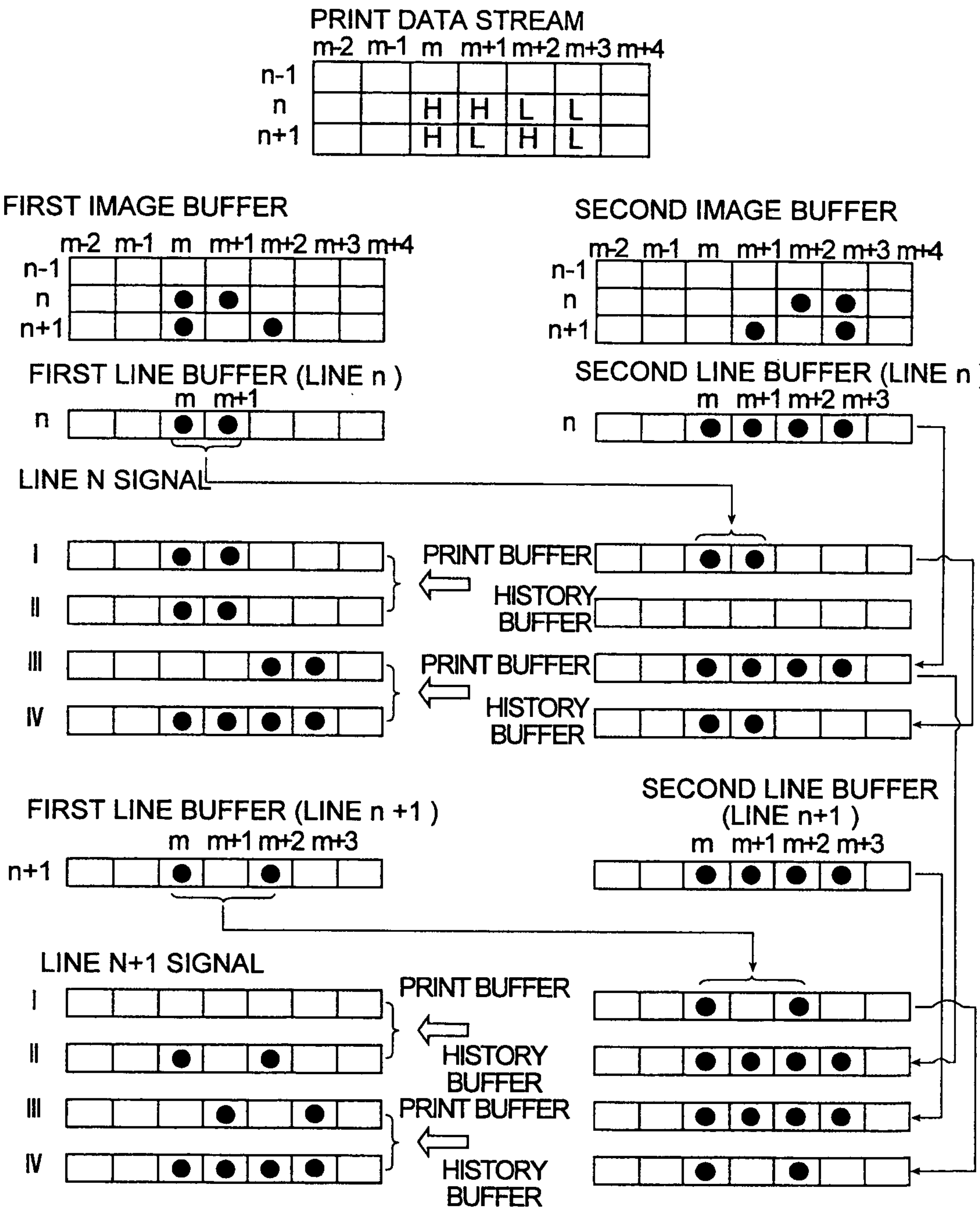
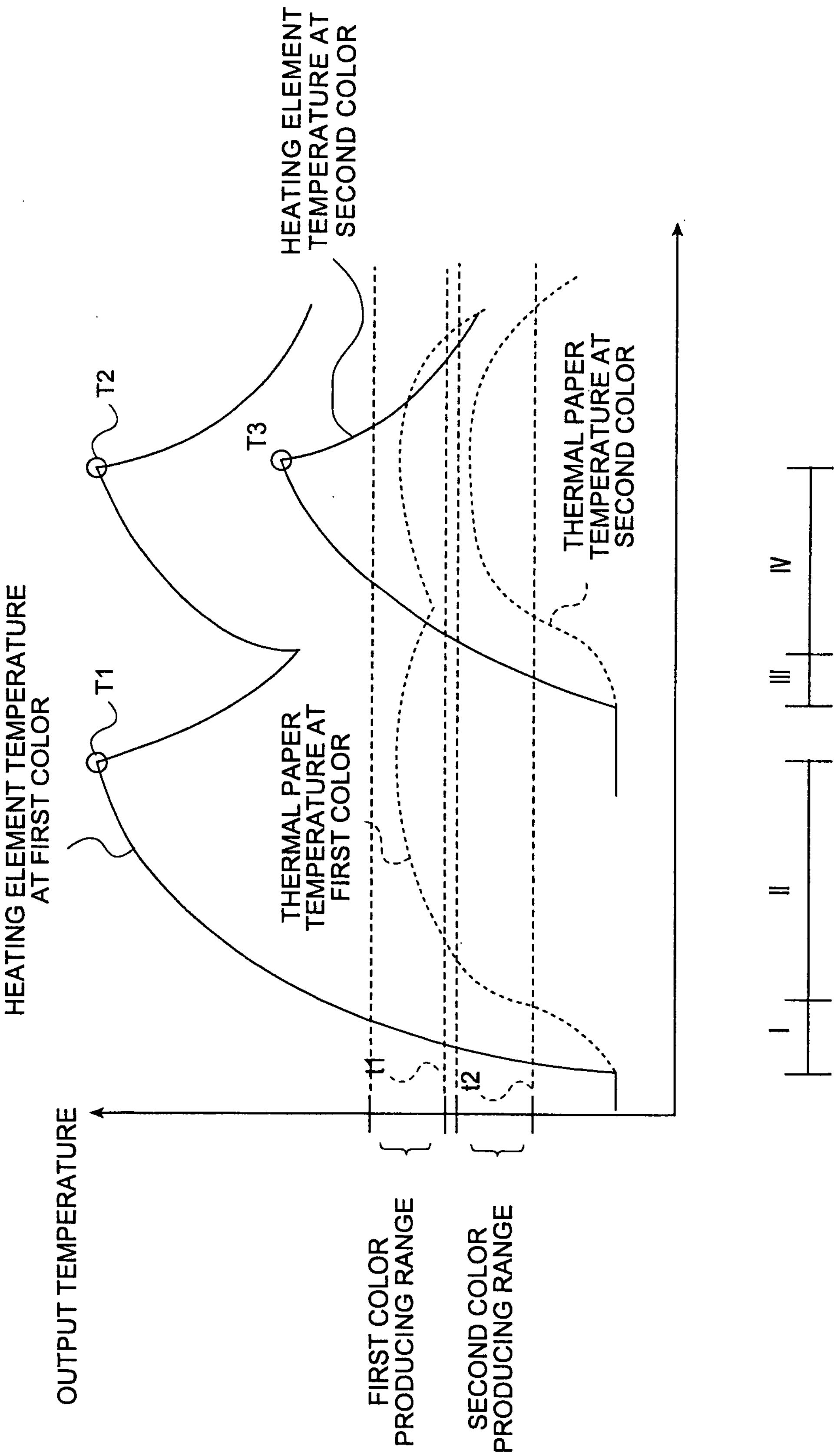

PRINT DATA STREAM
m-2 m-1 m m+1 m+2 m+3 m+4
n-1
n
n+1
H H L L
H L H L
FIRST IMAGE BUFFER
SECOND IMAGE BUFFER
FIRST LINE BUFFER (LINE n)
SECOND LINE BUFFER (LINE n)
LINE N SIGNAL
I
II
III
IV
PRINT BUFFER
HISTORY BUFFER
FIRST LINE BUFFER (LINE n +1)
SECOND LINE BUFFER (LINE n+1)
LINE N+1 SIGNAL

FIG. 7



OUTPUT TEMPERATURE
HEATING ELEMENT TEMPERATURE AT FIRST COLOR
T1
T2
T3
HEATING ELEMENT TEMPERATURE AT SECOND COLOR
THERMAL PAPER TEMPERATURE AT FIRST COLOR
THERMAL PAPER TEMPERATURE AT SECOND COLOR
t1
t2
FIRST COLOR PRODUCING RANGE
SECOND COLOR PRODUCING RANGE
I
II
III
IV

FIG.8