(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 601 658 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **93203404.4**

(51) Int. Cl.^{5}: **B41J 2/36**

(22) Date of filing: **03.12.93**

(30) Priority: **09.12.92 EP 92203816**

(43) Date of publication of application:
15.06.94 Bulletin 94/24

(84) Designated Contracting States:
BE DE FR GB NL

(71) Applicant: **AGFA-GEVAERT naamloze vennootschap**
Septestraat 27
B-2640 Mortsel(BE)

(72) Inventor: **Meeusen, Dirk, c/o Agfa-Gevaert N.V.**
DIE 3800, Septestraat 27
B-2640 Mortsel(BE)
Inventor: **Tack, Henri, c/o Agfa-Gevaert N.V.**
DIE 3800, Septestraat 27
B-2640 Mortsel(BE)
Inventor: **Kaerts, Erik, c/o Agfa-Gevaert N.V.**
DIE 3800, Septestraat 27
B-2640 Mortsel(BE)

(54) Method for calibrating the heating elements in a thermal head of a thermal printing system.

(57) A method for calibrating the heating elements in a thermal head of a thermal printing system, containing initial configuration settings, at least for the highest value of resistance of a heating element (R_{max}) or the largest value of power which can be dissipated in each heating element (P_{min}), and comprising the steps of activating each heating element under simulated operational conditions taking into account said initial configuration settings, measuring the current through each heating element and calculating the resistance or the dissipated power of each heating element, to obtain new values for R_{max} or P_{min}.

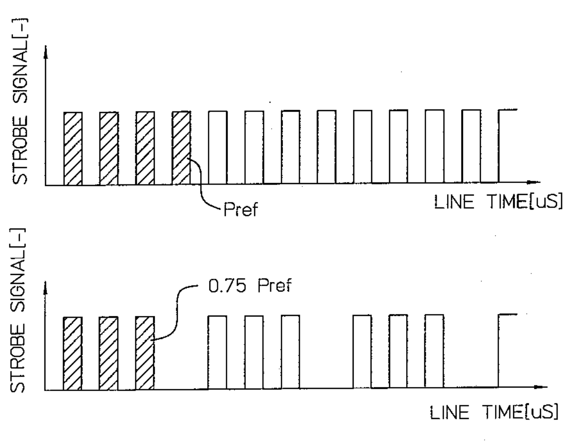


Fig.12

EP 0 601 658 A1

1. FIELD OF THE INVENTION

The present invention relates to thermal sublimation printing and more particularly to a method for calibrating the heating elements in a thermal head of said thermal printing system

2. BACKGROUND OF THE INVENTION

Thermal sublimation printing uses a dye transfer process, in which a carrier containing a dye is disposed between a receiver, such as paper, and a print head formed of a plurality of individual thermal heat producing elements which will be referred to as heating elements. The receiver is mounted on a rotatable drum. The receiver and carrier are generally moved relative to the print head which is fixed. When a particular heating element is energised, it is heated and causes dye to transfer, e.g. by sublimation, from the carrier to an image pixel in the receiver. The density of the printed dye is a function of the temperature of the heating element and the time the carrier is heated. In other words, the heat delivered from the heating element to the carrier causes dye to transfer to an image related to the amount of heat transferred to the carrier.

Thermal dye transfer printer apparatus offer the advantage of true "continuous tone" dye density transfer. By varying the heat applied by each heating element to the carrier, a variable dye density image pixel is formed in the receiver.

However, in systems utilising this type of thermal print head it is often observed that the printing density is not uniform across the page, but that lines, streaks, and bands are visible. This uneveness can arise from several causes, including variations in the resistance of different heating elements, variations in the mechanical or thermal contact between the thermal head and the dye layer, and variations in the thermal contact between the ceramic base of the head assembly and the heatsink.

US 4,827,279 discloses a method for measuring the uneveness in the image. According to this method, first a flat field is printed on a transparent receiver, then a microdensitometer measures the transmittance values of the receiver, then the digitised values are stored and finally these are used to adjust the number of heating pulses that are supplied to the heating elements.

A disadvantage of said method is the fact that this method requires the printing of a test-image which has to be measured by special equipment and the values need then to be brought in the printer. Therefor such calibration method can only be carried out by a service-technician. It would be more convenient if the customer himself could carry out a calibration of the printer by a calibration built in the printer or even more preferred where the printer would be able to periodically automatically calibrate itself.

3. OBJECTS OF THE INVENTION

It is a first object of the present invention to provide a calibration method that can be carried out by a customer or even may be carried out fully automatically without intervention of a customer.

Further objects and advantages wil become apparent from the description given hereinbelow.

4. SUMMARY OF THE INVENTION

We now have found that the above objects can be achieved by providing a method for calibrating the heating elements in a thermal head of a thermal printing system, containing initial configuration settings for the highest value of resistance of all heating elements (indicated as R_{max}) or the largest value of the time-averaged power that can be dissipated by each heating element (indicated as P_{min}) of said thermal head and comprising the steps of activating each heating element under simulated operational conditions taking into account said initial settings, measuring the current through each heating element and calculating the resistance or the dissipated power of each heating element, to obtain new values for R_{max} or P_{min}.

Further preferred embodiments of the present invention are set forth in the detailed description given hereinafter.

5. DETAILED DESCRIPTION OF THE INVENTION

Hereinbelow the present invention will be clarified in detail with reference to the attached drawings, without the intention to limit the invention thereto:

figure 1 is a principe-scheme of a thermal sublimation printer,

figure 2 is a data-flow-diagram of a thermal sublimation printer,

figure 3 is a cross-section of a thermal head,

figure 4 is a chart illustrating the variance in printing density across a page of a flat-field-print,

figure 5 is a chart illustrating the variance in initial resistance of the individual heating elements of a thermal head,

figure 6 is a chart illustrating the percentual change in resistance of a heating element versus the number of times that that element has been used,

figure 7 is a chart illustrating principally the activating strobe pulses of a heating element with an exemplary duty-cycle, figure 8 is a chart of a test-image pattern principally according to the present invention,

figure 9 is a chart of a test-image pattern as practically used in a preferred embodiment of the present invention,

figure 10 is a chart of a test-image pattern signal principally according to the present invention,

figure 11 is a chart of a test-image pattern signal as practically used in a preferred embodiment of the present invention,

figure 12 is a chart illustrating practically the activating strobe pulses of a heating element with an exemplary duty-cycle and with an exemplary skipping according to the present invention,

figure 13 is a circuit diagram describing the measurement according to the present invention.

Referring to figure 1, there is shown a global principe-scheme of a thermal printing apparatus that can be used in accordance with the present invention and which is capable to print a line of pixels at a time on a receiver or acceptor member (11) from dyes transferred from a carrier or dye-donor member (12). The receiver (11) is in the form of a sheet; the carrier (12) is in the form of a web and is driven from a supply roller (13) onto a take-up roller (14). The receiver (11) is secured to a rotatable drum or platen (15), driven by a drive mechanism (not shown) which continuously advances the drum (15) and the receiver sheet (11) past a stationary thermal head (16). This head (16) presses the carrier (12) against the receiver (11) and receives the output of the driver circuits. The thermal head (16) normally includes a plurality of heating elements equal in number to the number of pixels in the data present in a line memory. The image-wise heating of the dye donor element is performed on a line-by-line basis, with the heating resistors geometrically juxtaposed each along another and with gradual construction of the output density. Each of these resistors is capable of being energised by heating pulses, the energy of which is controlled in accordance with the required density of the corresponding picture element. As the image input data are denser, the output energy increases and so the optical density of the hard-copy image (17) on the receiving sheet. On the contrary, lower density image data cause the heating energy to be shortened, giving a lighter picture (17).

The different processing steps are illustrated in the diagram of fig 2. First a digital signal representation is obtained in an image acquisition apparatus (21). Then, the image signal is applied via a digital interface (22) and a first storing means (indicated as "memory" in fig. 2) to a recording unit (23), namely a thermal sublimation printer. In the recording unit (23) the digital image signal is processed (24). Next the recording head (16 in fig. 1) is controlled so as to produce in each pixel the density value corresponding with the processed digital image signal value (24). After processing (24) and parallel to serial conversion (25) of the digital image signals, a stream of serial data of bits is shifted into another storing means, e.g. a shift register (26), representing the next line of data that is to be printed. Thereafter, under controlled conditions, these bits are supplied in parallel to the associated inputs of a latch register (27). Once the bits of data from the shift register (26) are stored in the latch register (27), another line of bits can be sequentially clocked into said shift register (26). As to the heating elements (28), the upper terminals are connected to a positive voltage source (indicated as V_{th} in fig. 2), while the lower terminals of the elements are respectively connected to the collectors of the driver transistors (29), whose emitters are grounded. These transistors (29) are selectively turned on by a high state signal (indicated as "strobe" in fig. 2) applied to their bases and allow current to flow through their associated heating elements (28). In this way a thermal sublimation hard-copy (17 in fig 1) of the electrical image data is recorded.

Figure 3 is a detailed cross-section of a thermal head, indicated as part 16 in figure 1. Herein, we perceive a heatsink (31), a temperature sensor (32), a bonding layer (33), a ceramic substrate (34), a glazen bulb (35), a heating element (36 in fig. 3, being equivalent to 28 in fig. 2) and a wear-resistant layer (37).

In systems utilising this type of thermal print head it is often observed that the printing density is not uniform across the page, but that lines, streaks, and bands are visible in the direction parallel to the page motion. This nonuniformity occurs even when the input to the thermal head represents a so-called "flat-field", meaning that the inputs are identical, and thus that all of the heating elements are heating in response to the same constant input. Said variance in optical density from one position to another across the width of a print head, for flat fields, is graphically illustrated by Fig. 4. In searching for a solution to the indicated problem, we experienced that even for similarly constructed heating elements contained within one thermal head, there might be an initial variance between the density output created by one heating element versus the density output created by another heating element with both of the heating elements receiving pulses of equal type at the same time.

We also experienced that said density variance increases as the number of pulses applied to each increases. Further, it is often observed that the size of the density uneveness varies with the amount of heating, the actual temperature and the lifetime of the thermal head. Thereabove, those elements which dissipate a higher power will cause sooner a loss of glossiness in the printed image, due to higher local temperature peaks.

These differences in densities on the printed paper, visible as vertical stripes over the length of the page, can be explained by differences in the temperature present in the donor-acceptor-consumables, attained by differences in the power dissipated by the heating elements.

These differences in temperature and in power can arise from several causes including variations in the resistance of the heater elements (see parts 28 in figure 2 or 36 in figure 3), variations in the thermal or mechanical contact (37) between the thermal head and the dye layer, and variations in the thermal contact between the glazen bulb (35) and the substrate (34) of the head assembly (31).

There is an initial difference in the resistance values of the resistor elements in a thermal head caused by small inhomogeneities during the production process. Figure 5 is a chart illustrating the differences in initial resistance of the individual heating elements of a thermal head.

As the heating member becomes worn, its resistance changes and thereafter it breaks. During the lifetime of a thermal head the resistance values of the heating elements will change due to an aging process generally due to thermal oxidation of the resistor layer (ref 36 in fig. 3): the resistance value (R_e) of a heating element decreases depending on the number of the electrical pulses applied, typically -15% after some 10^8 pulses. So the more frequently an element is used, the faster its resistance value will decrease. In order to keep the print quality constant, these changes should be compensated. Fig. 6 shows a typical plot of percent (%) change in resistance of a representative one of the printhead elements or $\Delta Re/Re$ % drift, versus the number of times that the heating element has been pulsed. Note that as the number of pulses increases the thermal printhead resistance can decrease in value by about 15% and then start to rapidly increase.

Furthermore, the resistance for each element within the print head may change in a unique, independent manner, so that the initial Gaussian distribution of resistance of individual elements is not maintained throughout the operating life of the print head.

In order to illustrate said variances by practical numerical values, we experienced that the resistance value R_e (e.g. nominally 2600 Ω) of every resistor element can be different: between several thermal heads there can be an initial "between-variation" of about ± 15% regarding the nominal resistance value (e.g. between 2210 Ω and 2990 Ω); within one thermal head there can be an initial "within-variation", e.g. assymetric differences of -5% to + 10% regarding same said nominal resistance value; later on, due to aging, the resistance value of the individual heating elements can vary up to minus 15% .

It has been found that an extremely important parameter causing uneveness in the image is the deviation of the actual resistance or the actual power of the heating elements from their initial settings. Consequently, by measuring the actual resistance or the power of the heating elements in a thermal printing system, new settings therefor can be obtained that can be stored in the printer and used to compensate uneveness.

According to the present invention, we provide a method for calibrating the heating elements in a thermal head of a thermal printing system, containing initial configuration settings at least for the highest value of the resistance (R_{max}) or the largest value of the time-averaged power that can be dissipated by all heating elements (hereinafter referred to as P_{min}) and comprising the steps of activating each heating element under simulated operational conditions taking into account said initial settings, measuring the current through each heating element and calculating the resistance or the dissipated power of each heating element, to obtain new values for R_{max} or P_{min}.

Because of the facts that the resistance value and the dissipated power of an heating element are strongly dependent on their temperature (which itself is not known exactly), and secondly the fact that the exact values of the parameters of the analytical relations between the values at room temperature and at operational temperatures are not available, it is not easy to guarantee results with high accuracy if making the measurements at room temperature and afterwards recalculating the results to any other temperature. Thus, we take the approach by making the measurements under nearly real printing conditions, preferably with contact between the head and the drum but in abscence of any consumable, which can be compensated for in the measurement method in accordance with the present invention. The resulting simulated operational conditions aim to attain in each heating element of the thermal head the same temperature (e.g. T_e = 150 °C) in accordance with the configuration settings as laid down in the system-calibration when the printer was leaving the factory.

Of course, a calibration in presence of the donor- and acceptor-consumables is also possible in connection with the present invention and would be more accurate and even does not need any specific compensation for the abscence of the consumables during said calibration. But, the practical possibility of calibration in abscence of the consumables, as described in the present invention delivers to the consumer an enormous advantage in that no consumables have to be wasted, which results in a low calibration-cost and additionally in less ecological garbage.

As the temperature of the heating elements is generated by the electrical power dissipated in each heating element when activated by a power supply with voltage V, we citate the well-known formula

$$P_e = (V^2) : R_e \quad [1]$$

which clearly shows that, in general, a measurement of the resistance of the heating element (R_e) relates, though inversely, to the electric power (P_e) and hence to the temperature of the heating element (T_e).

The mathematical minimum power -being the largest power that can be generated by all the heating elements of the thermal head- thus occurs at the highest values of the resistances, symbolicaly abbreviated as R_{max}, and amounts for

$$P_{min} = (V^2) : R_{max} \quad [2]$$

As the method of the present invention aims to calibrate under simulated operational conditions, including a flat-field situation, the activating power of all the heating elements has to be equal. This can preferably be attained by restricting the power of each heating element down to the power (P_{min}) as dissipated in the heating element with the highest resistance value (R_{max}), which itself may be determined by measurement of the current through each heating element.

In a preferred embodiment of the present invention, the activation of the heating elements is executed pulse-wisely, in a special manner as indicated in Fig. 7, which shows the current pulses applied to a single heating element (ref 28 in Fig. 2). The repetition strobe period (t_s) consists of one heating cycle (t_{son}) and one cooling cycle (t_s - t_{son}) as indicated in the same fig. 7. The strobe-pulse width (t_{son}) is the time an enable strobe-signal (ref "strobe" in fig. 2) is on. The duty-cycle of a heating element is the ratio of the pulse width (t_{son}) to the repetition strobe period (t_s). In a printer in connection with the present invention, the strobe period (t_s) preferably is a constant, but the pulse-width (t_{son}) may be adjustable, according to a precise rule which will be explained later on; so the duty-cycle may be varied accordingly. Supposing that the maximal number of obtainable density-values attain N levels, the line time (t_l) is divided in a number (N) of strobe pulses each with repetition strobe periods t_s as indicated on fig. 7. In the case of e.g. 1024 density-values (according to a 10-bits format of the corresponding electrical image signal values), the maximal diffusion time would be reached after 1024 sequential strobe periods.

As mentioned above, before delivery of a printer to a customer, each apparatus is calibrated at the factory. Herein the initial settings for which the printer is configured include a reference resistance value, being the resistance value of the heating element which actually has the highest value of all heating elements (e.g. R_{max} = 2600 Ω) and/or a reference time-averaged power (e.g. P_{min} = 62 mW). Said initial settings for which the printer is configured may further include:

- a reference voltage (e.g. V_{th} = 14.7 V)
- a reference strobe period (e.g. t_s = 17.58 µsec)
- a reference strobe pulse time (e.g. t_{son} = 13.2 µsec) or a reference duty-cycle (e.g. 75 percent)
- a reference ambient temperature (e.g. T_a = 25°C)
- a reference thermal head temperature (e.g. T_{th} = 25°C)
- a small flat field printing pattern (e.g. 100 dots x 100 dots)
- cooling of the thermal head by an electrical fan built in the printing apparatus
- type of consumables to be used with the printer.

For a number of settings, deviations from their initial settings will occur due to one or more of the above-mentioned influencing parameters, so that after some time of operation a reconfiguration of the initial settings will be needed.

Opposite to the prior art as described in e.g. EP 0 458 507 which activates rather continuously by pulse-width modulation, in a preferred embodiment of the present invention, the pulse-wisely activation of the heating elements is used discontinuously, as already indicated in fig. 7. Therefor, it will be much more precise to measure the time-averaged electric power (indicated as P_{ave}) -in order to incorporate the duty-cycle- instead of the resistance value, and secondly -in order to attain a flat-field situation- it will be necessary to adapt the above formula to the time-averaged power that can be dissipated by all heating elements

$$P_{min} = [(V^2) : R_{max}]. (t_{son} : t_s) \quad [3]$$

The progress of technology attained by the introduction of time-averaged power measurements as described in the present invention, still brings a further advantage, namely in that possible unevenness in density due to inherent differences in switching characteristics (e.g. time delay, exponential rise-time, etc) are automatically weighted out.

Experiencing that said differences may result in differences in pulse profile and thus in differences in strobe-on time, practically up to about e.g. 90 nanosecondes, these time-differences in the prior art of pulse-number modulation may cause differences in density and even may accumulate. As in a preferred embodiment, the method of the present invention measures the time-averaged power, said differences are immediately corrected, no accumulation takes place and no unwanted differences in density are created.

In a next preferred embodiment of the present invention, said simulated operational conditions which are very close to the printing operational conditions, especially regarding the temperature in the heating elements, may further include predetermined values of the voltage applied to the thermal head (V_{th}) and predetermined values of the temperature of the thermal head (T_{th}) and of the temperature of the ambient (T_a).

This results from the knowledge that the maximum element temperature $T_{e,max}$, approximately reached after some 3 to 5 thermal time constants, depends on the thermal characteristics of the thermal head and of the consumables (being carrier or donor ref 12 in fig. 1 and acceptor or receiver 11 in same fig. 1) and on the applied voltage and accompanying strobe duty cycle

$$T_{e,max} = [(k_1) \times (T_{th})] + [(k_2) \times (T_a)] + + \{(k_3) \times [-(V_{th} - V_{ls})^2 / Re] \times (t_{son} / t_s)\} \qquad [4]$$

Herein, (V_{th} - V_{ls}) is the real voltage activating the heating elements, and equals the power supply (V_{th}, see fig. 2) minus the voltage dropped over the logical switching circuit (e.g. V_{ls} = 0.2 Volt) which was schematicaly represented by a switching transistor (ref. 29 in fig. 2) and R_e is the resistance of a heating element.

The above-mentioned pulse-wisely activation of the heating elements preferably will be executed with a measurement duty-cycle, defined in a preparatory step, and calculated from a mathematical model. Said model prescribes the time-averaged power dissipated in a heating element, on the basis of the electronic formula

$$P_{min} = [(V_{th} - V_{ls})^2 : R_{max}]. (t_{son} : t_s) \qquad [5]$$

Herein, R_{max} represents the highest resistance value of the heating elements as contained in the initial settings.

From another point of view, we experienced that the time-averaged power dissipated in a heating element can also be expressed by the next formula

$$P_{ave} = c_1.T_{th} + c_2.T_a + c_3.(V_{th})^2 \qquad [6]$$

In accordance with the present invention, the really applied thermal head voltage (V_{th}) is measured, the real ambient temperature (T_a) is measured (e.g. by the temperature of the drum) and the real thermal head temperature (T_{th}) is measured. Bringing these values in the aforementioned mathematical model [6], the numerical value of P_{ave} can be calculated and then brought into equation [5]. Herefrom, a specific measuring duty-cycle (t_{son}/t_s) can be defined by adapting the strobe pulse width (t_{son}), knowing the fixed value for the strobe period (t_s) which can be contained in the initial settings of the printing system. As a further consequence, the activation of the heating elements while measuring may restrict the available power in each element to P_{min}, as contained in the initial settings, to obtain the same operational temperature ($T_{e,max}$).

Preferably during the measurements of the heating elements, the puls-wisely activation of each heating element is effected in accordance with a special electrical test-image pattern, which allows every heating member to be tested. This pattern (symbollically illustrated in fig. 8) preferably includes lines of dots, wherein each dot represents a heating element: on each line one pixel is activated, while said activated dot of each line is sequentially moved across the pattern.

In a preferred embodiment of the present invention, the thermal head consists of e.g. 2880 heating elements and the test-image pattern is basically a white page with 2880 lines, wherein every line contains exactly one heated pixel, further indicated as "test-dot". The position of said pixel in every line is equal to its line number (e.g. 0 to 2879), so that the resultant measurement path runs diagonaly across the test-page (see fig. 8).

Figure 10 is a chart of an electrical test-image pattern signal during the measurements of the heating elements, according to the present invention, and thus allocates one test-dot pro line from the top-left to the right-bottom of the (soft) page.

According to the method of the present invention, each test-dot is preferably energised with a digital value corresponding to the density-value for which the human eye has the highest sensitivity for visual perception in the output print on the receiving material of density differences around this density-value . We have found that for output prints on black and white transparent film, said highest sensitivity appears at an optical density of about 1.

More in particular, one of the preferred embodiments further completes the generating of said test-image pattern by the following signals: pro said test-dot and in the same line a number of neighbouring dots on the left and on the right of the generated central dot are switched on and off. It results herefrom that the aforementioned diagonal

test-line (fig. 8), in reality now becomes a diagonal test-band (fig. 9). Whereas fig. 10 gives a principal electrical test-image pattern signal corresponding to said diagonal test-line, figure 11 is a chart of an electrical test-image pattern signal of a preferred embodiment as it is practically applied to each central test-dot, which thus is surrounded at its left side and at its right side by e.g. 50 pixels with a value of the image signal somewhat lower as the measuring density-value (e.g. 923).
As a global consequence of the activation of the neigbouring elements, and the diagonal test pattern and the thermal inertia or time-constant of the thermal head, the measurement method of the present invention thus simulates the flat field conditions which were also used in the factory-calibration.

Thanks to the policy of generating an electrical test-image pattern without printing any test-page on a receiver, the measurement can be carried out without the need for any consumable, which is a great advantage of the present invention for the customer. Further advantages lie in the facts that the calibration can be carried out fully automatically, without the need for a service-technician and in the fact that new settings for the resistance or the dissipated power of each heating element are automatically brought into the system.

When no contact between the thermal head and the drum is made during the measurement, the thermal head is not thermally loaded by the carrier nor by the receiver and per consequence the temperature $T_{e,max}$ will be somewhat higher then during printing. To avoid this unwanted temperature rise, the strobe pulse width is decreased according to a constant amount in temperature, preferably between 30 and 50 degrees (° C), or according to an amount in power, preferably about 30 percent (%). This correction is integrated in the mathematical model further taking into account the actual types of consumables.

In accordance with the present invention, during the puls-wisely activation of each heating element according to the generated electrical test-image pattern, the current through each heating element is measured, this in order to obtain the power dissipation and the resistance values and the heating elements.

First, pro central test-dot (as illustrated in fig. 8 and 10), during an activated strobe pulse (t_{son}, as illustrated in fig. 7) the instantaneous value of the current (I_e) of the heating element corresponding to said test-dot is measured. Physically, this current is defined by

$$I_e = (V_{th} - V_{ls}) / R_e \qquad [7]$$

During the same strobe-period (t_s as illustrated in fig. 7) also the average value of the current I_{ave} is measured. Physically, this current is defined by

$$I_{ave} = P_{ave} / (V_{th} - V_{ls}) \qquad [8]$$

After said measurements (pro central dot) of I_e and I_{ave}, and since (V_{th}-V_{ls}) was already measured before, the time-averaged power (P_{ave}) now can be calculated according to the next relation

$$P_{ave} = (V_{th} - V_{ls}) \times (I_{ave}) \qquad [9]$$

Finally, the resistance of each separate heating element (R_e) can be derived from the just mentioned measurements of currents by rearrangement of formula [7]

$$R_e = (V_{th} - V_{ls})/I_e \qquad [10]$$

In summary, the activation of the heating elements preferably according to the electrical test-image pattern is followed by measuring pro central dot the instantaneous current (I_e) and the corresponding time-averaged current (I_{ave}), calculating pro central dot the time-averaged power (P_{ave}) and by calculating pro central dot the resistance of the corresponding heating element (R_e).

Referring to Figure 13, there is shown a functional circuit diagram describing a preferred embodiment for measuring the required values. In order to measure the current through a heating element (indicated as R_1 and R_2 in fig 13, or as ref 131 in fig. 13, equivalent to ref 28 in fig. 2, or ref 36 in fig. 3) of the thermal head, the power wires (133a, 133b) can be disconnected by means of a power relays (134a). Also the capacitors (135) parallel on the power supply (132), which itself is adjustable but stabilised by an electronic regulator (136), can be disconnected by means of a relays (134b). The minus-wire (133c) of the thermal head is connected to the virtual ground (137) of an operational amplifier (138). The current (I_e) through the heating element (131) is fed through a high precision resistor (139) with resistance R_{prec} used as a feedback resistor to said operational amplifier and the voltage drop (V_o) over this high precision resistor is measured in two different ways, namely instantaneously and time-averagedly, by

$$V_{01} = I_e \times R_{prec} \qquad [11]$$

and by

$$v_{02} = I_{ave} \times R_{prec} \qquad [12]$$

To save time, the two measurements, I_e and I_{ave}, are preferably done at the same time. Therefore these values are preferably kept in a sample and hold device (141a, 141b) at the moment the central test-dot (e.g. strobe pulse 1023) is applied. Then said measured values are converted from analog to digital values by an analog to digital convertor (140) and stored in a memory means.

To obtain the instantaneous and the time-averaged values of the current (I_e, I_{ave}), low pass filters may be used. Hereto fig. 13 indicates a low pass filter (142b) for the measurement of I_{ave} and a switchable low pass filter (142a) for the measurement of I_e. Since at this stage of the method according to the present invention, there are already known for each heating element of the thermal head the numerical values for P_{ave} [calculated with formula 9] and for R_e [calculated with formula 10], the new values for R_{max} or P_{min} may be retrieved and be used in order to attain good eveness in the printed density.

As the diffusion process for a pixel is a function of its temperature, the printed density is a function of the applied power. To obtain equal densities, the available time-averaged power for every heating element may be made equal and preferably equal to the power of the heating element actually producing the lowest time-averaged power (P_{min}) and was determined in the foregoing measurement procedure. The equalising of the power in the heating elements may be realised in two consecutive steps, which now will be explained.

First, because the power dissipated by the element with the lowest power can increase during the lifetime of the thermal head and also because another element can become reference element -as is described extensively in the aforementioned detailed description of the measurement method- , in a next calibration, the eventually increased power of the actual reference element may be kept constant by reducing the pulse duration of the strobe pulses and thus reducing the duty-cycle accordingly (cf. fig. 7). Thus, while printing, all heating elements may be activated with a reduced, but common duty-cycle.

Second, as all other heating elements could dissipate more power as the actual reference element, the further and individual reduction of the power of said other elements may preferably be done by skipping a number of heating pulses (see fig. 12). By said skipping a number of heating cycles of those heating elements that generate too much instantaneous power, the time-averaged power of all heating elements becomes equal and so the temperatures of the elements do. Therefor, in a preferred embodiment of the present invention, the calibration method further comprises the sequential steps of first limiting the printing power of each heating element by commonly reducing the strobe duty-cycle of all heating elements, and secondly of skipping for each heating element an individual-apt number of strobe-pulses.

In reference to fig. 7 and supposing that the maximal number of obtainable density-values (or "heating-values") attains N levels, the line time t_l (e.g. t_l = 16 msec) is divided in a number of strobe pulses each with repetition strobe periods t_s (e.g. t_s = 16 μsec). In the case of e.g. 1024 heating-values, the maximal diffusion time would be reached after 1024 sequential strobe periods (N = 1024).

In order to keep, in every line and for a given print-density, the available energy per individual pixel constant, the individually compensated energy (E_{ic}) of a heating element should be equal to a reference energy (E_{ref}). Said reference energy per line is restricted below a physical upper-bound energy (E_{limit}) defined by the physical constraints of the printing system (regarding lifetime of the heating element, melting or burning of the carrier or the receiver consumable, loss of glossiness of the printing material) and may be laid down in the initial configuration settings

$$E_{ic} = E_{ref} < E_{limit} \qquad [13]$$

Explicitating this equation [13] by

$$(P_{iave}) \times (N_c) \times (t_s) = (P_{ref}) \times (N_{ref}) \times (t_s) \qquad [14a]$$

wherein P_{iave} is the time-averaged power dissipated in a heating element with index i, P_{ref} = P_{min} being the time-averaged power dissipated in the reference heating element and e.g. N_{ref} = 1024 being the number of strobe-periods pro line-time.

As the strobe period (t_s) is a constant (cfr. initial settings), equation [14a] reduces to

$$P_{iave} \times N_c = P_{ref} \times N_{ref} \qquad [14b]$$

from which

$$N_c = (P_{ref}/ P_{iave}) \times (N_{ref}) \qquad [15]$$

The number of energy quanta (N_{ref} - N_c) is not applied to the resistor element with index i, but skipped, as illustrated by the timing diagram of fig 12. This figure 12 is a chart illustrating practically the activating strobe-pulses of a heating element (with an exemplary duty-cycle and exemplary skipping) according to the present invention.

In the upper part of said figure 12, a pulse-train is drawn as activating the reference heating element (with R_{max} or P_{min}), thus generating the restricted power as it is available in the actual printing cycle, after reducing the common duty-cycle as it was necessary to compensate the power for decrease of the resistance during the lifetime. In the lower part of figure 12, a corrected pulse-train is drawn as activating another heating element with e.g. R_e

= 0.75 R_{max} and which in the absence of the present invention, would dissipate e.g. 25 percent of energy above said reference (thus 125% E_{ref}). As illustrated by fig. 12, every fourth strobe pulse may be skipped. In this way, to obtain equal densities for equal image signal data, the available time-averaged power for every heating element may be made equal and preferably equal to the power of the heating element actually having the lowest time-averaged power (P_{min}) or the highest resistance (R_{max}).

By equalising the power to all heating elements, also the individual temperature profiles will become equal, meaning that the evolution of the temperature of the heating elements in function of the diffusion time will show the same curvature (e.g. T_e rises exponentially up to 150 °C in about 30 ms).

Although the invention has been described with respect to preferred embodiments, it is not to be so limited, as changes and modifications can be made within the intended scope of the present invention defined by the appended claims.

It is clear that while measuring in accordance with the present invention, at the same occasion one could detect when a resistor becomes out of range. If the actual value of the resistance of a heating element lies outside the tolerances of e.g. 15% of the initial value, a "resistor out of range error" indication could be displayed to the customer.

The measurement of the resistance of each heating resistor, conducted by means of an R-measurement test pattern, may occur at the power up of the system, after a number (e.g. 300) of prints, after a change of consumable, etc.

As the calibration method described in the present invention accounts for deviations in the resistance or the dissipated power of each heating element as prescribed in the initial configuration settings, within the same scope, also compensations may be made in order to reach good printed eveness regarding other parameters, such as voltage drop of the power supplied to the heating elements, evolution of the ambient temperature during the calibration, etc. This invention may be used as well for grey-scale thermal sublimation printing as well as for colour thermal sublimation printing. Further, the printing may be applied in graphic representations, in medical imaging, in facsimile transmission of documents etc.

Claims

1. A method for calibrating the heating elements in a thermal head of a thermal printing system, containing initial configuration settings, at least for the highest value of resistance of all heating elements (R_{max}) or the largest value of power that can be dissipated in each heating element (P_{min}), and comprising the steps of activating each heating element under simulated operational conditions taking into account said initial settings, measuring the current through each heating element and calculating the resistance or the dissipated power of each heating element, to obtain new values for R_{max} or P_{min}.

2. A method according to claim 1, characterised in that the activation of the heating elements is executed pulse-wisely.

3. A method according to claim 2, characterised in that the activation of the heating elements is in accordance with an electrical test-image pattern.

4. A method according to claim 2, characterised in that said simulated operational conditions include the largest value of time-averaged power that can be dissipated in each heating element (P_{min}).

5. A method according to claim 4, characterised in that said simulated operational conditions further include predetermined values of the voltage applied to the thermal head and values of the temperature of the thermal head and of the temperature of the ambient or the temperature of the drum.

6. A method according to claim 2, characterised in that the pulse-wisely activation of the heating elements, while measuring, is executed with a duty-cycle calculated from a mathematical model for the time-averaged power dissipated in a heating element, taking in account a value for the voltage applied to the thermal head as defined by actual measurement, with a resistance value as defined by the previous measurement and with a fixed value for the strobe repetition period as contained in the initial configuration settings.

7. A method according to claim 3, wherein said generating of an electrical test-image pattern comprises the allocating of one central-test-dot pro line from the top-left to the right-bottom of the page or vice-versa and the pro said test-dot switching on and off of a number of neighbouring dots on the left and on the right of the generated central dot and in the same line.

8. A method for equalising the available power of each heating element in a thermal head of a

thermal printing system, while printing, comprising the steps of first limiting the available printing power of each heating element to the power that can be dissipated in the heating element with the highest value of resistance of all heating elements (R_{max}) or to the largest value of power that can be dissipated in each heating element (P_{min}), by commonly reducing the strobe duty-cycle to all heating elements, and secondly by skipping to each heating element an individual-apt number of strobe-pulses.

9. A method according to claim 8, wherein said skipping to each heating element of an individual-apt number of strobe-pulses is a time-equidistant skipping.

10. A thermal printer including a thermal head having a number of heating elements, means for selectively activating each heating element, the improvement comprising: means for containing initial configuration settings for R_{max} or P_{min}, means for activating each heating element under simulated operational conditions taking into account said initial configuration settings, means for measuring a current through each heating element and calculating the resistance or the dissipated power of each heating element and means for obtaining new values for R_{max} or P_{min}.

11. A thermal printer according to claim 9, wherein the activation of the heating elements is executed pulse-wisely with an adjustable strobe duty-cycle, further comprising means for equalising, while printing, the available power of each heating element by first limiting the printing power of each heating element by commonly reducing said strobe duty-cycle to all heating elements, and secondly by skipping to each heating element an individual-apt number of strobe-pulses.

12. A thermal printer according to claim 11, wherein said skipping to each heating element of an individual-apt number of strobe-pulses is a time-equidistant skipping.

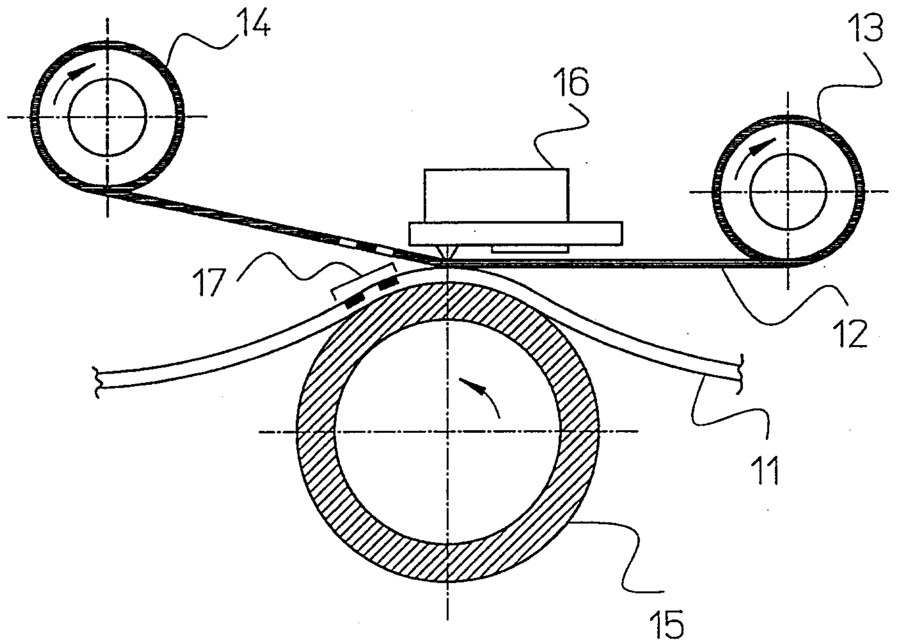
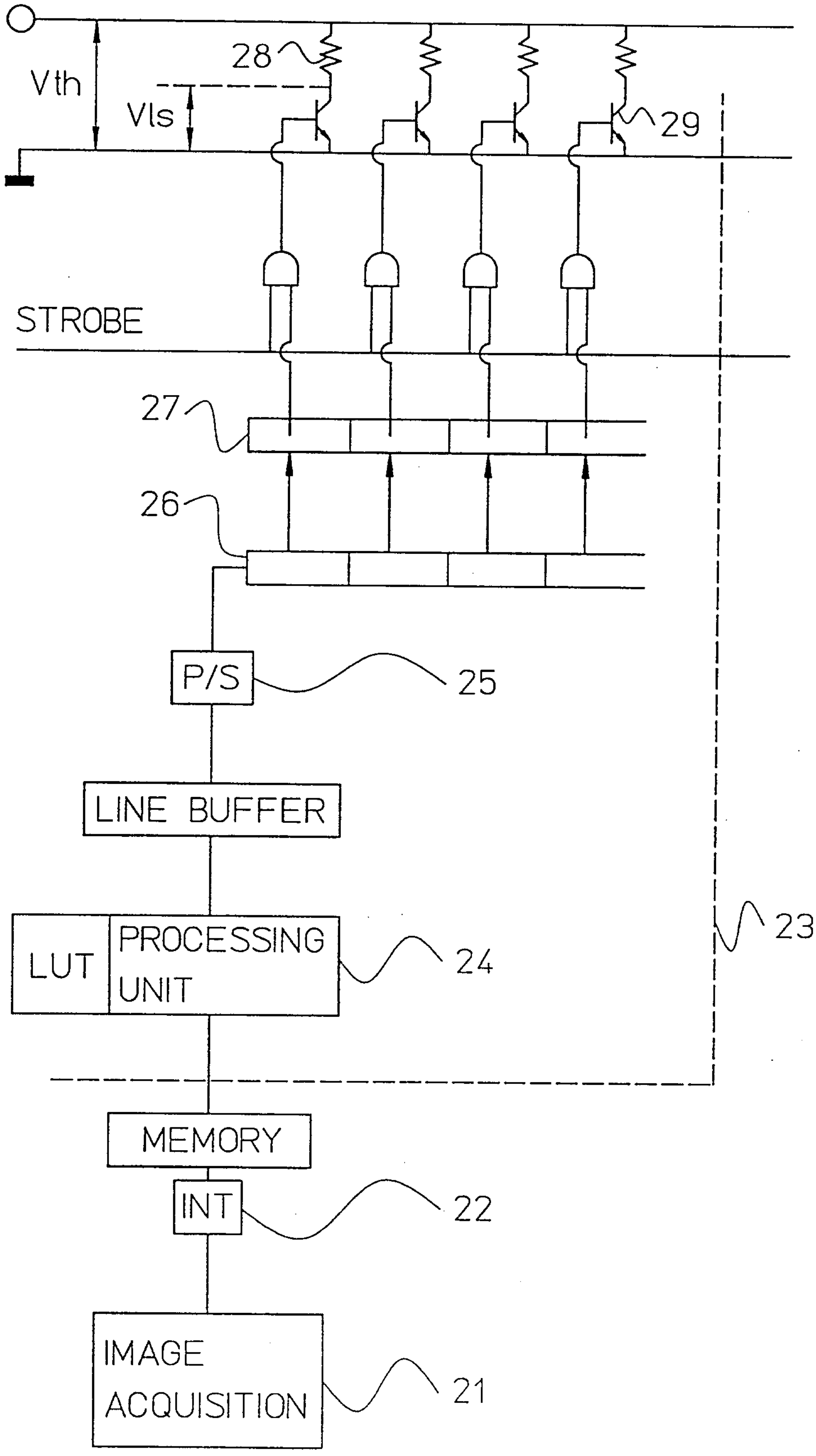


Fig.1



Vth
Vls
28
29
STROBE
27
26
P/S
25
LINE BUFFER
LUT
PROCESSING UNIT
24
23
MEMORY
INT
22
IMAGE ACQUISITION
21

Fig.2

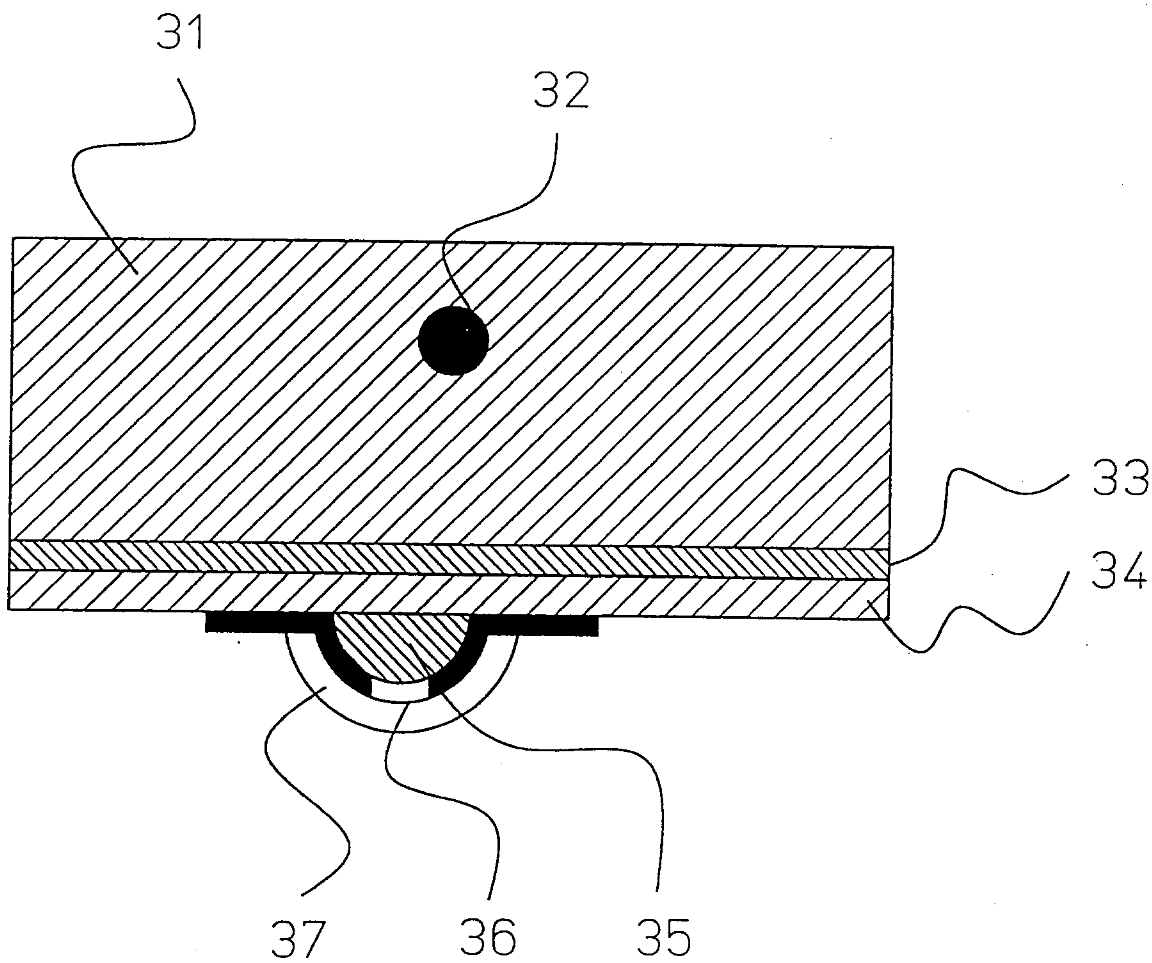


Fig.3

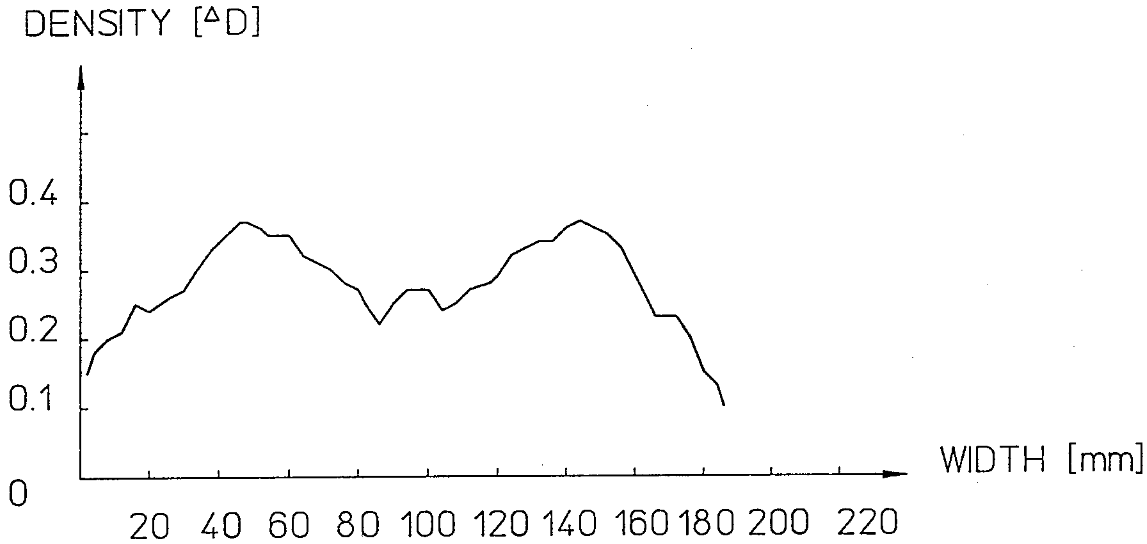

DENSITY [ΔD]
0.4
0.3
0.2
0.1
0
WIDTH [mm]
20 40 60 80 100 120 140 160 180 200 220

Fig.4

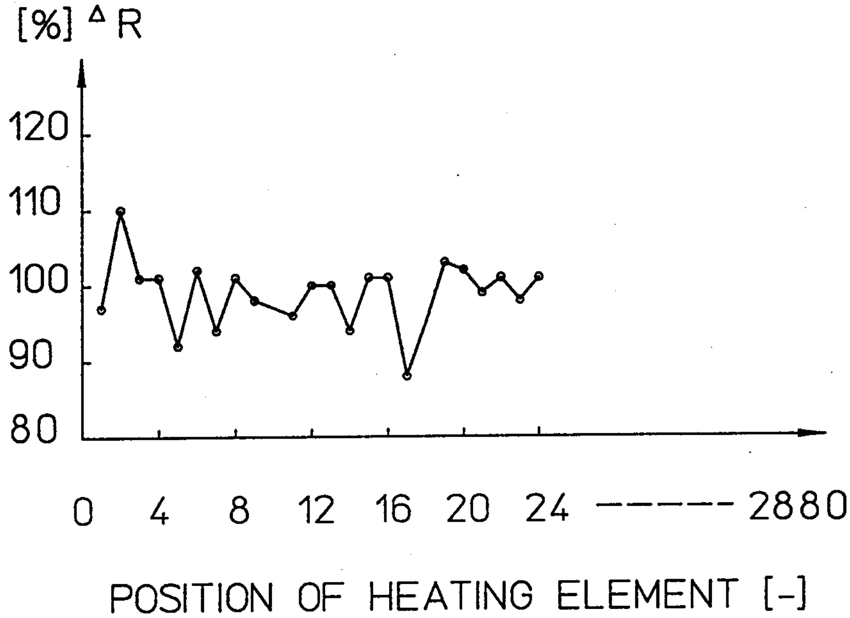

[%] ΔR
120
110
100
90
80
0
4
8
12
16
20
24
2880
POSITION OF HEATING ELEMENT [-]

Fig.5

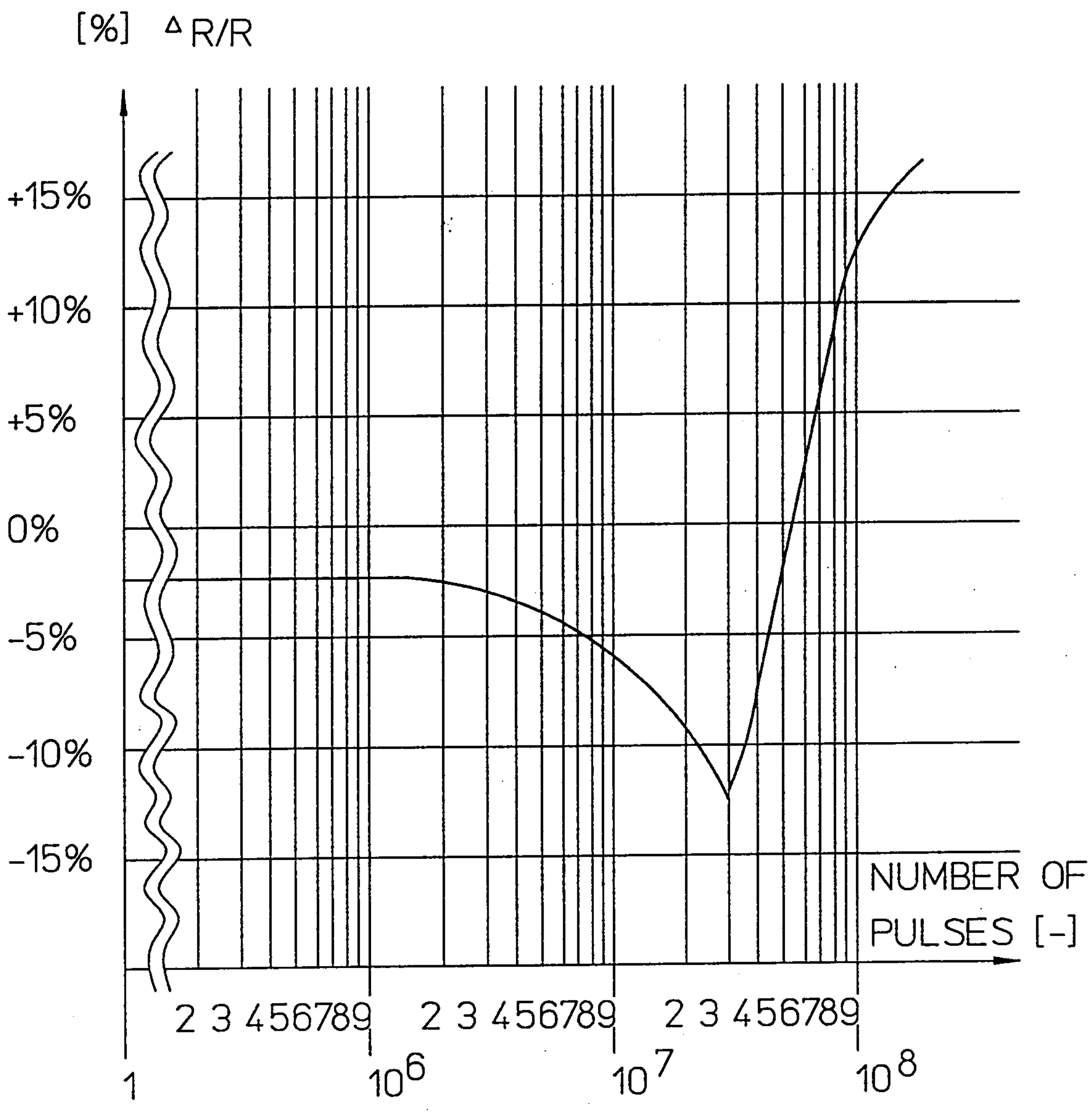

[%] ΔR/R
+15%
+10%
+5%
0%
-5%
-10%
-15%
NUMBER OF
PULSES [-]
2 3 456789
2 3 456789
2 3 456789
1
10^6
10^7
10^8

Fig.6

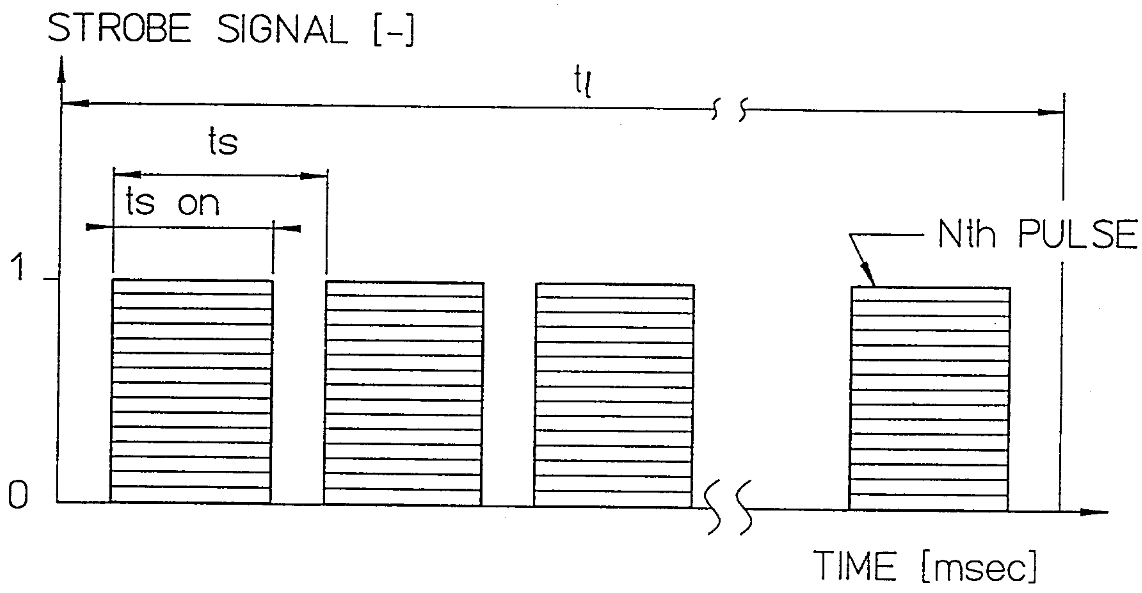


Fig.7

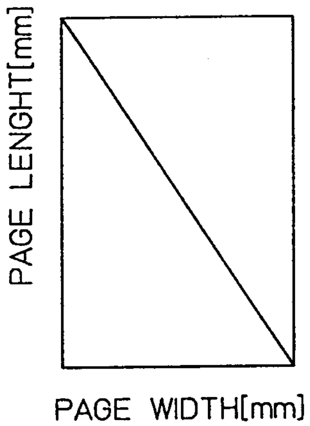


Fig.8

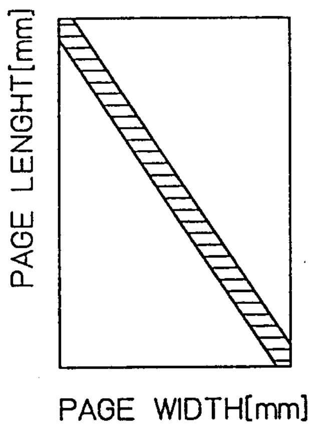


Fig.9

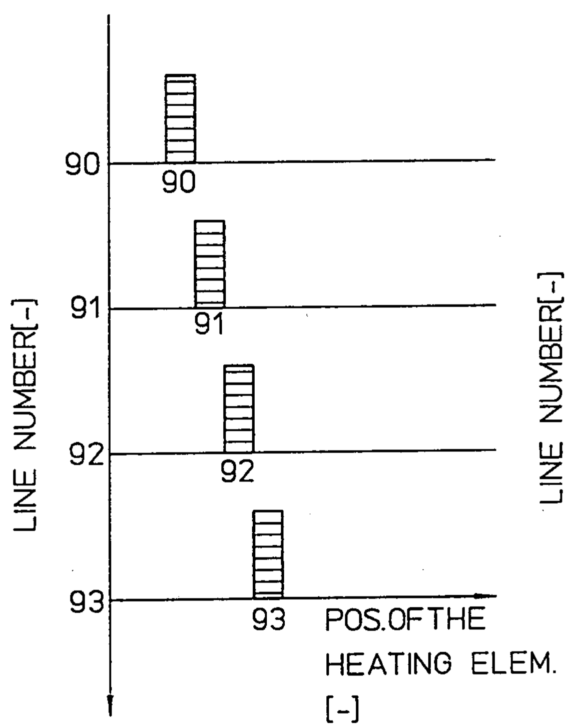


Fig.10

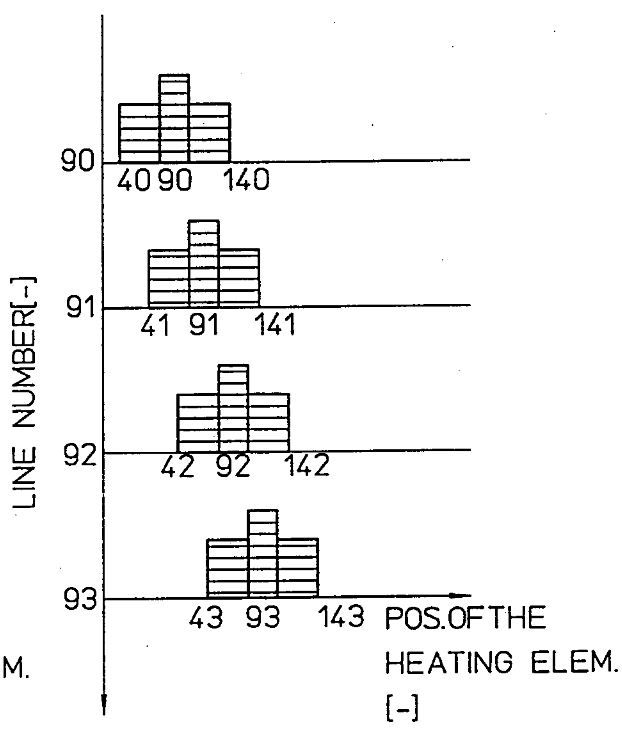


Fig.11

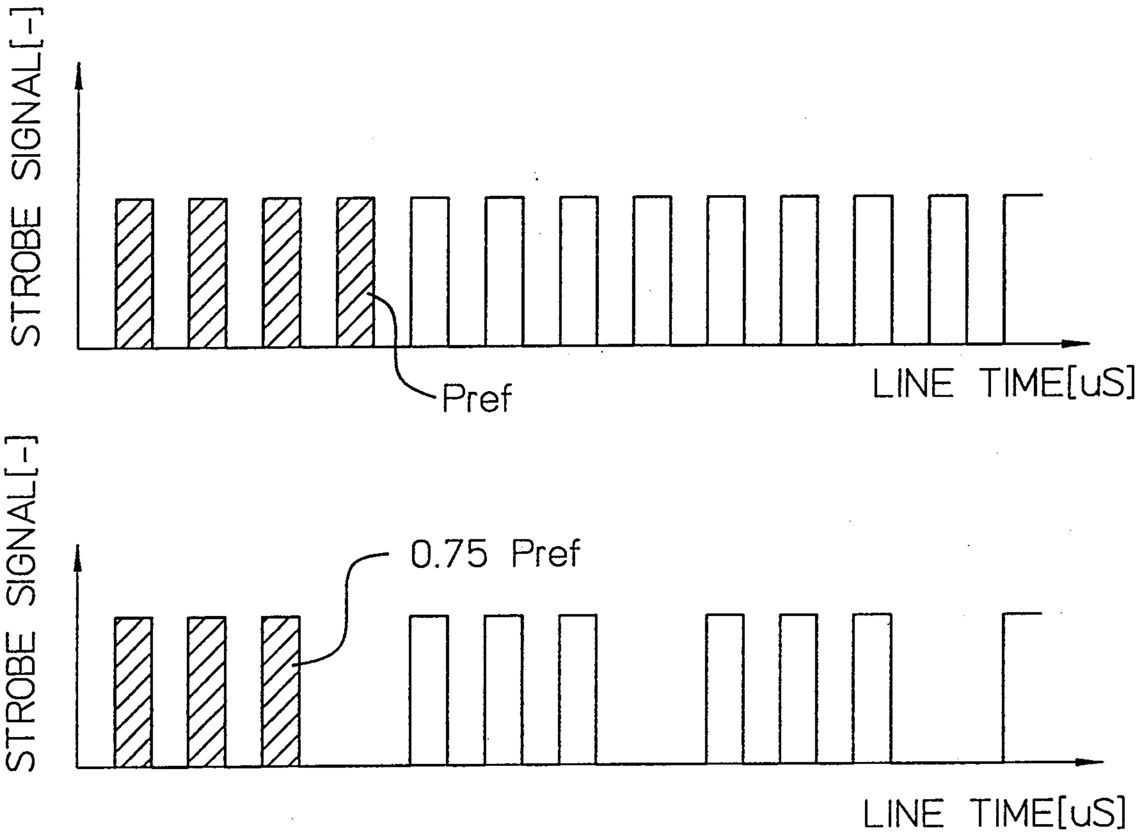

STROBE SIGNAL[-]
Pref
LINE TIME[uS]
STROBE SIGNAL[-]
0.75 Pref
LINE TIME[uS]

Fig.12

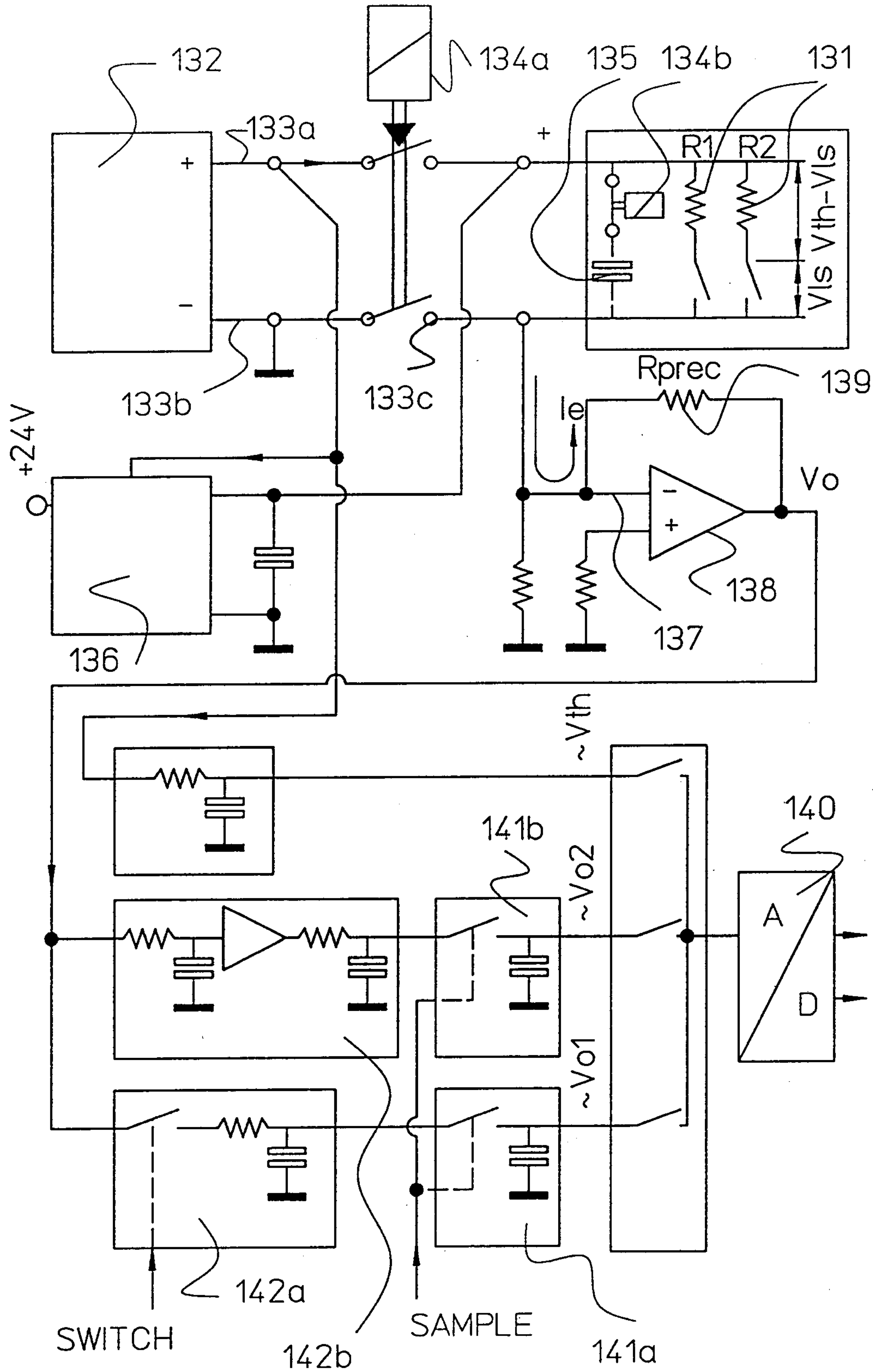

132
134a
135
134b
131
133a
R1
R2
Vls Vth-Vls
133b
133c
Rprec
139
Ie
+24V
Vo
138
137
136
~Vth
140
141b
~Vo2
A
D
~Vo1
142a
SWITCH
142b
SAMPLE
141a

Fig.13

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 20 3404

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
D,A	EP-A-0 458 507 (HEWLETT-PACKARD COMPANY) 27 November 1991 * abstract; claims; figures * ---	1,8,10	B41J2/36
A	WO-A-91 14577 (DOWTY MARITIME LIMITED) 3 October 1991 * page 8, line 9 - line 19 * * page 1, line 8 - page 5, line 9 * ---	1,8,10	
A	PROCEEDINGS OF THE FIFTH INTERNATIONAL CONGRESS IN ADVANCES IN NON-IMPACT PRINTING TECHNOLOGIES, 12 November 1989, SAN DIEGO, CALIFORNIA (US) pages 477 - 484, XP138923 E. SASAKI ET AL. 'high quality recording in thermal dye transfer printing' ---	2,8,9,12	
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 487 (M-778) (3334) 20 December 1988 & JP-A-63 209 954 (OKI ELECTRIC IND CO LTD.) 31 August 1988 * abstract * ---	1,8,10	TECHNICAL FIELDS SEARCHED (Int.Cl.5) B41J
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 244 (M-834) 7 June 1989 & JP-A-01 051 958 (FUJI XEROX CO LTD.) 28 February 1989 * abstract * -----	1,8,10	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 March 1994	Fontenay, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)