Development of dual-line wide-format 1200-dpi thermal print head

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Abstract

The wide-format dual-line 1200-dpi thick-film thermal head was developed utilizing the following technologies:

- *An alternated conductive lead circuitry inside the thermal head is devised. The circuitry does not use diodes for prevention of reverse current; instead, it adds a secondary power supply to redirect the reverse current.*
- *The 1200-dpi printhead is combined of two identical 600dpi nib lines with half-pitch offset in the nib line direction and separated by a distance of 32 nib lines in the printing direction.*
- *The printhead is manufactured by the direct dispensing system using the air micro technology which feeds back the pressure and controls the linear actuator to follow the surface of a substrate so that a heater nib line can be produced stably and accurately.*
- *Several wide-format (up to 54" width) products based on the 1200-dpi thermal print head have been designed and are capable of printing half-toned images of up to 133 lpi (line per inch).*

Introduction

Thermal printing systems have been widely used in kiosk, facsimile machines and engineering plotters due to the advantages of low cost, free of maintenance, and high printing speed. In the early days, for those applications low-resolution thermal heads would usually suffice.

As the printing applications move upwards to graphic and other high-end markets, high resolution thermal heads become a necessity and 600dpi is the base line requirement. To move upwards further, wide-format 1200dpi thermal heads seem to be the new standard.

This paper describes the development of a wide-format 1200-dpi thick-film thermal head and the innovations evolved during the course of development. These include the alternated conductive lead system without diodes, the direct dispensing system based on the air micro technology, and the formation of 1200dpi printhead by combining dual 600dpi nib lines.

The Alternated Conductive Lead System

The thermal head introduced in early days and widely used was 250 mm (B4 size) length. The technology was explored to develop the 1100 mm (44") 400dpi thermal head on a single substrate in 1994.[1]

The 44" wide-format thermal head used the alternated conductive lead system in which the downstream driver ICs and the upstream conductive circuits are shared by pairs of neighboring nibs at different times.[2]

The heating of nibs is controlled by switching between different paths from the power supply as well as turning on or off the driver IC based on the data bit being 1 or 0. Each conductive path is connected to a diode to prevent the reverse current from flowing back to the other path.

A simplified circuit diagram of the alternated conductive lead system is shown in Fig. 1. While the external controller sends data to be printed to the register in driver IC, in A-phase the power supply is connected to the conductive path A. Next, in B-phase it is connected to the conductive path B.

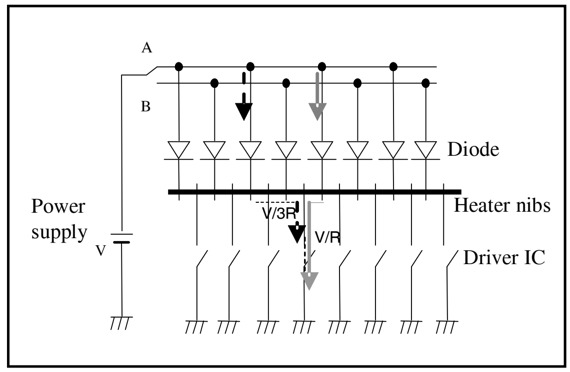


Figure 1 *Alternated conductive lead system thermal head with diodes*

The diode in the conductive circuit path is to prevent the reverse current from flowing back to the other conductive path. In the simplest case that only one driver IC is switched on, as shown in Fig. 1, the current flowing through the supposedly excited nib is V/R while the current flowing through the three neighboring nibs on the left side is only V/(3R). Since on each of these three nibs, which are not intended to be excited, the current is only 1/3 of the one on the excited nib, it generates only 1/9 of power. The magnitude of heat generated is still way below the reaction threshold for the printing media and thus its affect can be ignored.

For manufacturing purpose it is necessary to embed diodes into arrays with multiple elements mounted. However, if A- and B-phase are not dissociated completely, the leakage may occur between arrays. This requires extreme precaution during the developing of the print head.

By utilizing the alternated conductive lead system, only one half of conductive circuits and driver ICs need to be budgeted, easing the density requirement of pattern formation. Therefore, wide conductor lines can be used to achieve a reliable performance, and it also comes with the benefits of easiness for part inspection and correction/repair.

Development of 1200dpi Thermal Printhead

The development of 1200dpi head makes use of the following technologies:

- New formation method of a heater nib line
- Alternated conductive system without diodes
- Combination of dual 600dpi nib lines

New Formation Method of a Heater Nib Line

For low-resolution thermal heads, the pattern formation of conductive path and nib line can be achieved by means of screen-printing. The lower limit of width for which a heater resistance nib line can be formed reliably is about 0.15 mm (150 µm). In the case of 400dpi, generally good printing quality can be obtained by using 0.16-0.2 mm line width

For thermal heads of higher resolution, the requirement of conductor pattern density becomes more demanding, especially for 1200dpi heads, and it makes the manufacturing process more difficult. Furthermore, forming a nib line of narrow width with stability and consistency is more challenging due to the fact that the influence of the surge of a substrate on the thickness and width of a nib line becomes more detrimental.

For a 600dpi thermal print head, the width of nib line is 120-140 µm, compared to 160-200 µm in a 400dpi head. For a 1200dpi head formed by dual 600dpi nib lines, the width requirement is 90-110 µm.

To form a heater resistance nib line, two methods are available. One is screen-printing, the other is the direct drawing system using the dispenser. As mentioned above, since 150 µm is the minimum achievable width by screen-printing, it becomes unsuitable for forming a 600dpi or 1200dpi head. Therefore, we have turned to the use of a micro dispensing system which can detect the surge of a substrate and draw heater element line more stably and accurately [3].

A dispensing system is usually composed of a surface-following subsystem and a discharging device. It detects the surge of a substrate, usually using a touching stylus or a laser device, and moves up/down following the surface curvature while the discharging device dispenses fluid. The use of a touching stylus, however, is problematic to our application since it may create scratches on a conductive pattern when touching the substrate. A laser device, though offering the advantage of free of contact, presents technical complications to be incorporated in our system, however.

Our approach is to devise a micro dispensing system which has the desirable surface-following capability to draw the nib line on the substrate accurately. The block diagram of the micro dispensing system is shown in Fig. 2.

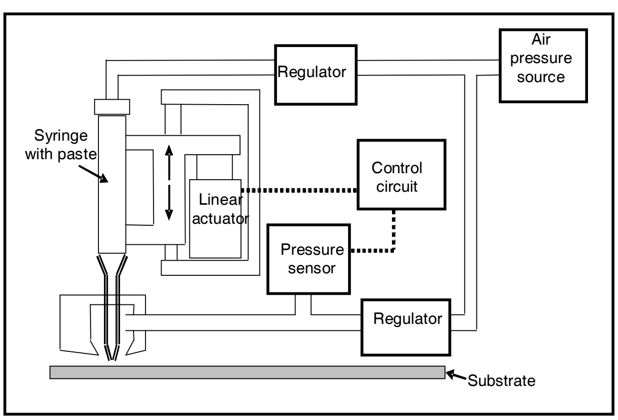


Figure 2 *Block diagram of micro dispense system*

In the system a pressure sensor is used to detect the change in back pressure at the tip of the nozzle due to the variance in the gap between the nozzle and the substrate. The sensed pressure is used as the feedback signal to control a linear actuator so that the gap between the nozzle and the substrate can be maintained constant. The sensed and control signals are shown in Fig. 3 for a test substrate with a surge.

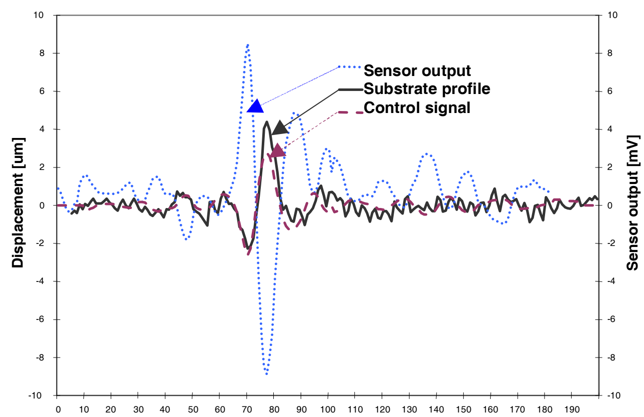


Figure 3 *Micro Dispense System control and output data*

The capillary used for wire bonding has been adopted in our dispensing system. The production quality has been good that a narrow width of down to 80 µm can be formed stably. The nib line formed by using the micro dispense system on the substrate is shown in Fig. 4, with the one by screen printing also shown for comparison.

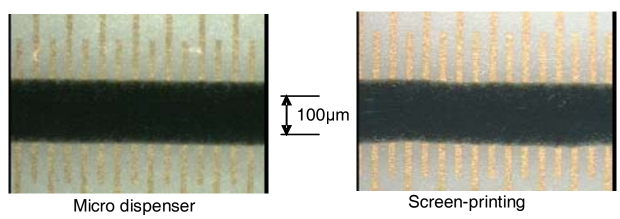


Figure 4 *The enlargement of the nib line formed by micro dispensing system and screen printing*

Alternated Conductive System without Diodes

For thermal heads utilizing the conventional alternated conductive lead system, diode arrays are required. However, for high-resolution thermal heads the space allowed for mounting the diode arrays is small, which in turn requires forming a deep diffusion zone during the manufacturing process. Therefore, the addition of diode arrays may present problems of technical difficulty as well as manufacturing cost.

These considerations have led us to adopt the approach in which the diodes are removed and a secondary power supply is added. This additional power supply is of 1/3 magnitude of the primary one and, at any time, is always connected to the conductive path which the primary power supply is unconnected. A simplified circuit diagram of the system is shown in Fig. 5.

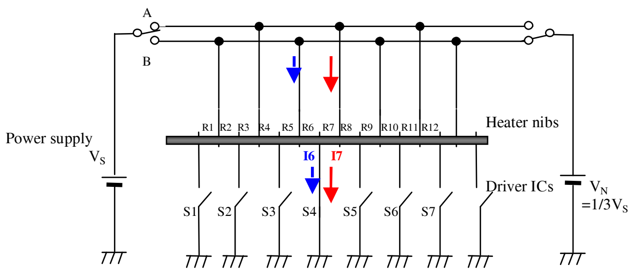


Figure 5 *The thermal head and power supply circuit without diodes*

The role of the secondary power supply can be illustrated by comparing the alternated conductive lead system without diodes, in Fig. 5, to the one with diodes in Fig. 1.

Consider the case that the switch S4 of driver IC is closed. It is to have the current flow into the heater nib R7, which is to be excited with the current of V_S/R. In Fig. 5, the voltage of $1/3V_S$ is applied to all the heater nibs that are connected to the conductive path B, and it effectively limits the current flowing into nib 6 to 1/3 of V_S/R, as in the case with the diodes in the circuit in Fig. 1.

Note that $1/3V_S$ is always applied to the heater resistance nibs and, when the temperature on the nib elements becomes high, the small energy generated may still cause thermal reaction on the printing media and result in undesirable imaging affect. Therefore, the switching of power supplies needs to be synchronized very precisely with the strobe signal of driver IC, as shown in Fig. 6.

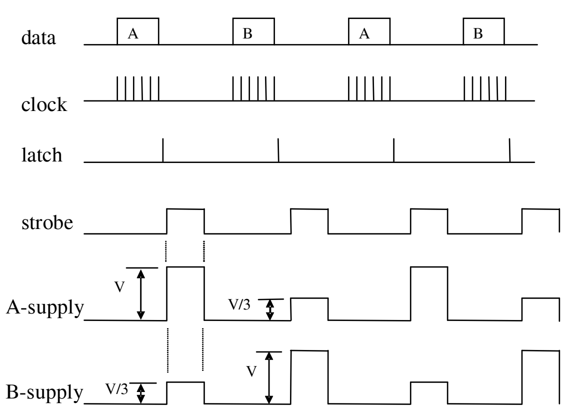


Figure 6 *Thermal head control timing for the circuit without diodes*

Shown in Fig. 7 is the circuit diagram of the power supplies V_S and V_N ($=1/3V_S$). The current path of flowing in/out depends on the ON/OFF state of the driver ICs inside a thermal head. The secondary power supply V_N serves two functions: a sink path for the main power supply (V_S) to flow out and a source path for the current to flow into the driver IC.

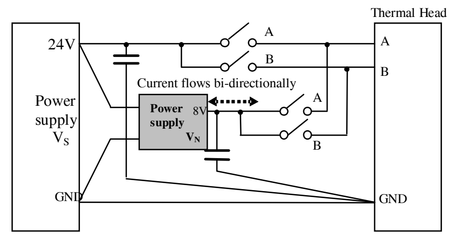


Figure 7 *Power supply circuit for an alternated conductive system without diodes*

The flow of the current inside the thermal head when not printing is shown in Fig. 8. In that case, all the currents are flowing from V_S through all the nibs into V_N. On the other hand, when printing one full nib line (i.e., all the heater elements), the current does not flow into V_N since all the switches of the driver ICs are ON. Therefore, careful consideration should be taken, with proper attention to the timing response and capacity matching, in the selection of power supplies and implementation of the power switching circuit.

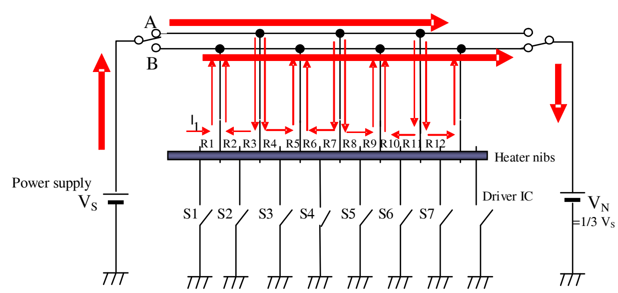


Figure 8 *Flow of current inside thermal printhead when not printing*

As compared to the conventional alternated conductive lead system with diodes, the system using a secondary power supply is easier to control. This is because the conventional system is influenced by the structure of diodes and the characteristics of a semiconductor. With the elimination of diodes these variations do not exist. Thus the specification of parts can be relaxed, and the work of parts inspection is unnecessary, resulting in reduced labor cost.

In the test prints shown in Fig. 9 only one nib was printed repeatedly, and it can be seen that the influence of V_N on the neighboring nibs is negligible.

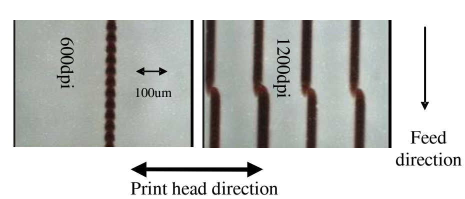


Figure 9 *Enlargement of one-element printing*

Formation of Dual-line 1200dpi Thermal Print Head

As mentioned above, the heater nib line can be formed stably by means of an air pressure micro dispensing system. Formation of heater nib line of narrow width can be realized through the optimal adjustment of operational parameters such as output pressure, drawing speed, selection of a nozzle and paste viscosity, etc. It has also been proved that the design is achievable via the use of the alternated conductive lead system without incorporating diodes in the circuit.

The formation of a 1200dpi thermal head is combined of two identical 600dpi nib lines. The approach is an extension of the pioneering feasibility study [4] in which a 600dpi thermal head is formed by combining two identical 300dpi nib lines. The design and formation procedure of 1200dpi thermal heads are as follows:

- Draw two 600dpi heater resistance nib lines, with the gap set to 0.677 mm (32x1200dpi lines).
- Since 1200dpi is formed by two 600dpi nib lines, make wide conductive path for dot and heat separation.
- Arrange the 1200dpi pattern to be of symmetrical conductive pattern, using commercial driver ICs with a shift register and a latch, so that two directions of data transfer are performed simultaneously into each heating nib line.
- Communalize power supplies for both nib lines.

The conductive path diagram is shown in Fig. 10 and the enlarged view of heater resistance nibs is shown in Fig. 11

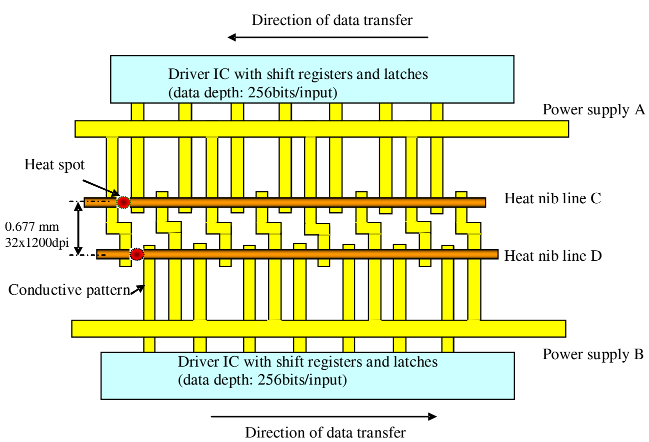


Figure 10 *The conductive path diagram of 1200dpi thermal head*

Note that for the case of narrow conductive path, as shown in the left side in Fig. 11, each 600dpi nib line may produce round-shaped dots suitable for 600dpi imaging, but an image of 1200dpi may lose the clarity it deserves due to interlacing of two 600dpi nib lines. Therefore, wide conductive lead pattern should be used as shown in the right side.

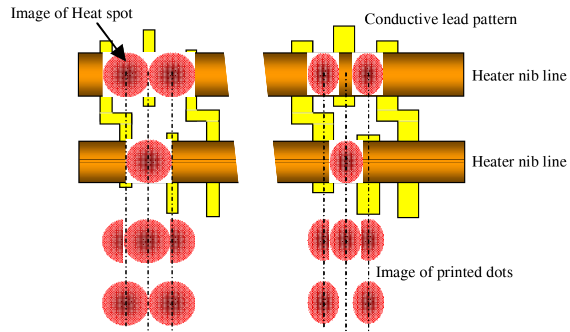


Figure 11 *Form of nib pattern with narrow and wide conductive paths*

Spec of a 1200dpi 54" Thermal Head

Listed below is the specification of a 1200dpi 54" thermal head:

- Effective printing width: 1365 mm (54 inches)
- Platen diameter: 70 mm Max.
- Data depth in the shift register: 256 bits
- Number of data input ports: 63
- Typical heater resistance value: 3000 ohms

In order to provide the mechanical rigidity for the printing system, a bigger platen may be used. Data depth in the shift register is set to 256 bits to minimize the data transfer time for the sake of high-speed printing as well as the implementation of micro pulse control and history control. The metal bar is used inside a thermal head to minimize the wiring/conductor resistance and the accompanying voltage drop. The cross-sectional structure including platen of this thermal head assembly is shown in Fig. 12.

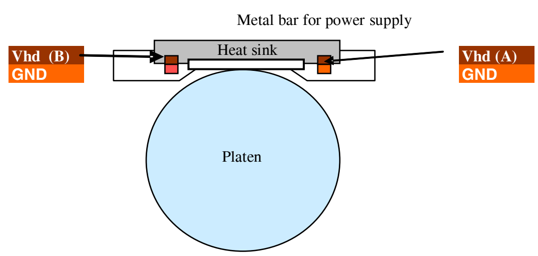
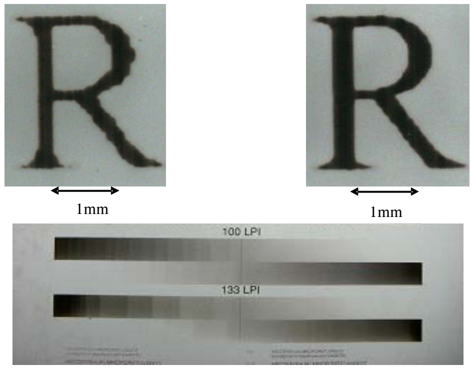


Figure 12 *Cross-sectional structure of thermal head*

The printed samples using 1200dpi and 600dpi thermal heads are shown in Fig. 13. The character 'R' is an enlargement from the original 6-point font. Not surprisingly, the curve and the slanting line are expressed more smoothly in 1200pdi. Similarly, printings of a belt in gray scale (half-toned dots) are also shown, and grading can be expressed continuously in 133 lpi when using 1200dpi thermal head.



600dpi 1200dpi

Figure 13 *Printing samples*

Summary

Development of a wide-format (up to 54”) 1200dpi thermal print head was realized by utilizing the following approaches.

By means of the micro dispensing system which uses the air back pressure for feedback to achieve accurate surface-following, the uniform heater resistance line can be formed stably by eliminating the influence of the surge of a substrate. With this equipment, the narrow-width nib line, which cannot be formed using the conventional screen-printing method, can be achieved and the exothermic domain also made small.

The diodes required in the conventional alternated conductive lead system could be eliminated by adding a secondary power supply instead. In this approach, the circuitry composition inside a thermal head is simplified and the thermal head of high resolution can be realized easily.

The 1200-dpi printhead is combined of two identical 600dpi nib lines with half-pitch offset in the nib line direction and separated by a distance of 32 nib lines in the printing direction.

During the course of development several related patents have been applied and granted. Several wide-format (up to 54" width) products based on the 1200-dpi thermal head have been designed and are capable of printing half-toned images of up to 133 lpi.

Future Development

While the resolution of 1200dpi for the wide-format thermal head will be prevailing for a while, there are two areas for improvement.

The first one is the on-head circuitry and electronics control. The goal is to have most head-dependent functions migrated from the external master controller to an intelligent microcontroller mounted on the thermal head. With this kind of decoupled configuration it will be more efficient to improve performance in image quality and printing throughput. It also has the benefit of building the whole printing system quicker and more reliable.

The other area is the mechanical structure of the thermal head. The wide-format 1200dpi thermal head is of conventional flat type. While sufficing for use on film imagesetters and paper plotters, its performance can be improved further for systems requiring function of ribbon’s peel-off such as direct-to-screen applications. Thus the development of corner-edge thermal head is another area to be explored.

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Author Biography

Takeshi Toyosawa obtained his B.S. in Chemistry from Akita University, Japan in 1979. He worked at GRAPHTEC Corporation Research and Development from 1979 to 2004. Since 2005 he has been with OYO Geospace Corp, and is continuing R and D in wide format high resolution thermal print head.