Segmented Multi-Digit Thermal Printhead

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Abstract

Current thermal printing applications are dominated by the line-type printheads, although other types have been utilized in the past. A new, segmented printhead type has been developed having multiple digit / character capability that offers simpler mechanical operation than either as no transverse movement between the printhead and thermal media is required. Electronic control is simpler, as well, as the number of segments or dots to drive are fewer to form the figure. For example, one figure can be formed by controlling 8 segments while 35 dots are required if formed using a traditional 5x7 matrix. The drawback of the segment type is that the range of figures is pre-determined; mainly suitable for numeric and special character figures. A demonstrable product has been developed having four numeric, three alpha symbols and punctuation. Challenges were to enhance readability by minimizing gaps between segments and to minimize production cost. Each figure consists of one common electrode and multiple heating element or segment electrodes. A multiplexing driver circuit minimizes the number of connections. Image density is adjusted by controlling supplied energy (applied voltage), "on time" or duty cycle; based on the thermal history.

History of Thermal Printheads

Thermal printing technology came into the main stream in the 70's with applications like calculator and terminal printer [1]. This was a combined effort of thermal printer hardware manufacturers and the thermal media suppliers. There were various types of thermal printheads in the beginning, such as matrix type and formed font type [2]. The original segmented type printhead came out about that time [3], also.

In the 80's and early 90's, small serial thermal printheads became very popular as they were employed for typewriters by replacing the impact formed font units and also new breed of non-alphabet typewriters called "word processors".

A new application market exploded in the thermal printing technology when facsimile usages became very popular. The second wave of high-volume usage application came when the POS (point of sales) receipt printer applications moved from the impact dot-matrix technology to the thermal technology.

The latest thermal printing usages are seen on photo printers. The development of line-type thermal printheads is one of the key attributes for those three new emerging applications.

Line-type Thermal Printhead

The thermal printer world today utilizes the line-type printheads almost exclusively as other types of printheads had all disappeared or had been replaced by other technologies such as inkjet and electro-photography. There are mainly 4 different head configurations the line-type printhead based on the location of the heating elements on the ceramic substrate and in relation to the driver circuit. They are referred to as a center, edge, near-edge or true-edge printhead.

Today, typically two production methods are used in industry: thick-film and thin-film technology. Thick-film technology uses conductive and resistive materials in paste form and screen print onto the ceramic substrate. The substrate is heat-treated in the kiln. Thin-film technology utilizes the sputtering process as the materials are placed with the substrate in a vacuum chamber to perform physical vapor deposition.

The thermal printing is accomplished with the line-type printhead as shown on Fig. 1 and Fig 2.

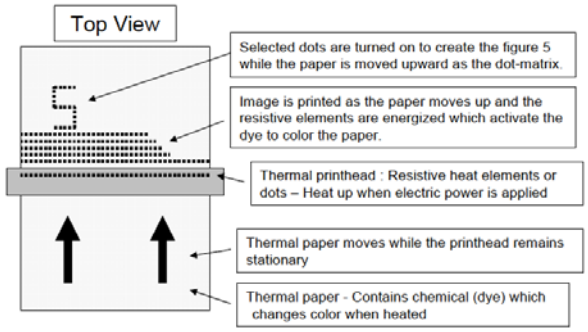

Figure 1 Line-type printhead printing process: top view

Thermal printing process using the line-type printhead requires the paper movement mechanism since the images are formed as matrix of dots.

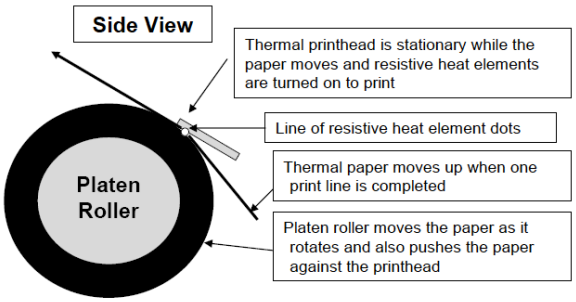

Figure 2 *Line-type printhead printing process: side view*

Unique thermal printing application

A unique thermal printing application emerged where a single line of fixed font data needs to be printed. The idea was to employ the thermal technology to be used in time clock card printing. Traditionally, time clock card was printed with the

mechanical method, such as formed font or impact dot matrix mechanism. However, the current and popular methods of thermal printing, employing line-type printhead did not seem appropriate to the special requirements of a time clock application:

- Mechanical systems to move either the paper or printhead, relative to each other, would prove to be a reliability problem in this application
- Mechanical transport systems and heat sink requirements would exceed the manufacturing budget for the time clock
- Paper is of a traditional time card format; not suitable for special dispensing
- Both print head and media must be low-cost
- Paper is manually and visually aligned with the print head
- Paper (time card) is hand-held during printing; not machine fed from a spool or stack
- Paper (time card) must preserve its image for at least seven years

New segmented printhead concept

As the current line-type printhead would not meet the requirements of this application, a segmented thermal printhead was considered.

The idea of this type of printhead came out in the 70's, but there were no existing printhead available on the market. The new segmented multi-digit thermal printhead had to be designed for this application. Some innovations had to be made in order to meet the specification demands which included the following:

- 2 alpha characters and 5 numbers with a separator symbol
- Easy to read printed characters
- Character: Width 2.4 mm / Height 4.5 mm
- Character tilt: 7.5 degrees

The printing process concept with the segmented printhead is very different from the line-type head as shown on Fig. 3 below.

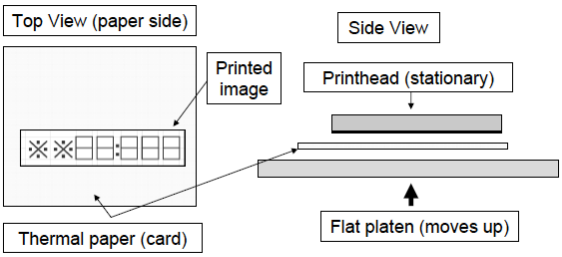

Figure 3 *Segmented printhead printing process*

Driving the segmented printhead

As shown on Fig. 3, mechanical driving method of segmented printhead is completely different from the line-type printhead which is illustrated on Fig 2.

Electrically, the segmented printhead does not have to be driven like line-type head which has to form the image by printing the matrix of dots. Since the segmented printhead heating elements do not have to be turned on repeatedly in very fast cycling time like a line-type head, data refreshing and tuning on/off cycle time requirements are less demanding and critical. Fig. 4 shows one numeric character schematic drawing.

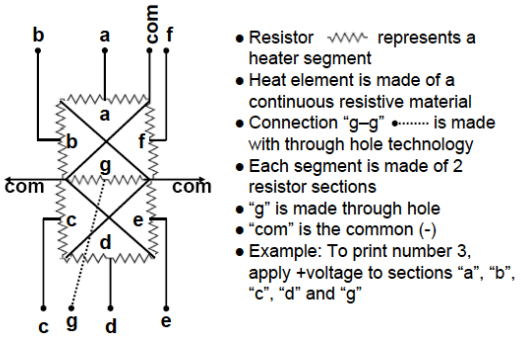

Figure 4 *Schematic drawing of numeric character*

New printhead design

Although the concept of the segmented thermal printhead has been around since the 70's, a new design was implemented to take advantage of new technologies currently available. The new and improved points are:

- Each numeric figure segment is consisted of two heaters for better heating distribution
- Two-sided/multi-layer design became much easier with through-hole technology
- Minute patterning became possible for screen process and equipment to utilize it
- Ink manufacturing improved with nano-particles for the mask screen
- IR voltage drop of the common pattern is minimized by increasing the thickness and making redundant / parallel paths
- The numeric font is rounded and tilted for easier reading
- Gaps between the segments are minimized as a result of narrower electrode pattern
- CADCAM was employed to take advantage of easier design work

Material improvement

The new design was possible because of the improvement for the materials of printhead over the years. Some of the improvements are:

- Each numeric figure segment is consisted of two heaters for better heating distribution
- Ceramic substrate material quality stabilized due to higher production quantity by the supplier compared with the 70's era.
- Multi-layer technology advancement and availability of the material with reasonable cost
- Under-glaze layer material improvement and layer flatness
- Coherency ability of conductive material to the ceramic substrate improved
- There is a wider selection of resistive materials according to resistance and TCR value with high adhesive characteristics and aging stability
- Higher quality and better anti-abrasion capability of protective over coating glass material
- RoHS compliant material requirements were added in the last several years

Manufacturing process improvement

Printhead manufacturing process improved over the years which made it possible to develop the new segmented head. Some of the note-worthy improvements are:

- The width of the conductor electrode is reduced to about 30 microns from 100 microns of old design
- Due to laser processing capability improvements, cutting and making holes on the ceramic substrate became much easier and inexpensive
- Manufacturing equipment are micro-processor-based controller for consistent and accurate / repeatable manufacturing processes

Change of thermal industry environment

Beside the printhead improvements and changes, there are substantial changes in the thermal industry environment in general. Some of the changes are:

- The cost of thermal paper decreased in spite of the capability improvement in the recent years
- The public acceptance of thermally printed documents became universal. In the earlier days, they were perceived as "non-permanent" printed documents and not good enough for legal usages
- Electronics around the printhead, such as driver circuit components, wiring technology, connecting technology and so on, became simpler, easier and less costly.

Final specifications of new printhead

By taking full advantage of the newer technologies and materials, the new printhead was designed. It was decided in the beginning that the thick-film technology will be used for this product. The final specifications of the segment printhead are as follows:

- Fig. 5 shows the overall external drawing of the new printhead
- Substrate is made of multi-layer ceramic material with dimensions of 7 mm width, length of 30 mm and thickness of 0.8 mm
- The materials used for the conductive pattern and electrode, glass glaze layer, resistive heating segment and over-coat glass are the same or with similar characteristics to the material used to manufacture the line-type thick-film thermal printhead
- The resistance value of heating segment is 240 Ohms which was designed to work with 24 V power supply
- There are 64 terminals on the substrate which are made of halved 0.4 mm diameter through hole structure

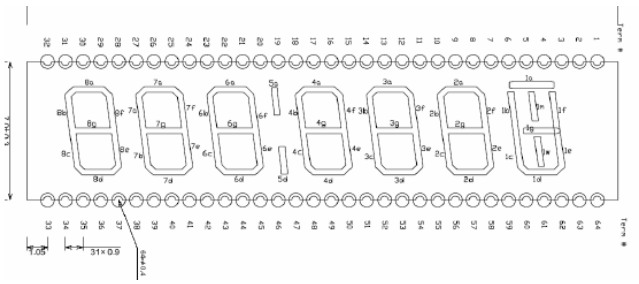

Figure 5 *Printhead external dimension drawing*

Magnified view of segmented digit

A magnified pattern of one digit and printed image are shown on Fig. 6 below. The gray portion of the pattern is the conductive layer and the black partition is the resistive material layer which makes up the heat element. The doted gray line is the connected via the through-hole between the termination and heat element. Note that the pattern and printed figure are mirror image.

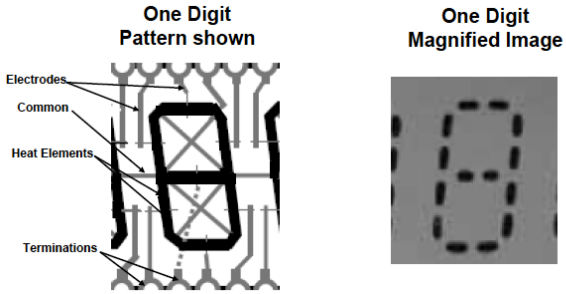

Figure 6 *Pattern layout and printed image*

P*rinthead in the* end product

Lathem Time Corp. of Atlanta, Georgia has been in the time clock business since 1919. During this history, the designs have incorporated variations on methods incorporating impact printing and inked ribbons. Some of these methods, which remain popular, are based upon electro-mechanical clock movements with engraved number wheels synchronized to rotating clock hands on a traditional dial. Newer models, offering flexible print formats, use a linear or matrix dot-impact print head that scans the time card under microprocessor control of a "worm screw". Negative characteristics of these methods include:

- Jamming of print ribbon or needle entanglement (dot-matrix type)
- Disturbing noise from platen impact or matrix scan
- Difficult print customization (print-wheel type)
- Messy job changing ink ribbons
- No protection against improper alignment of print head and media
- No market protection against third-party "consumables" (cards and ribbons)

The newly designed segmented multi-digit thermal printhead was incorporated in the newest time clock machine which eliminated the undesirable characteristics.

The cutaway drawing of the time clock is shown on Fig. 7 to illustrate the location of the printhead and how it is mounted in the unit.

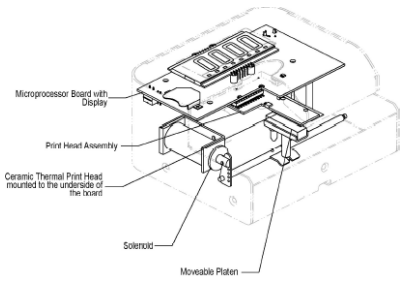

Figure 7 *Actual printhead usage*

Sample of time card printed with the thermal printhead is shown on Fig. 8.

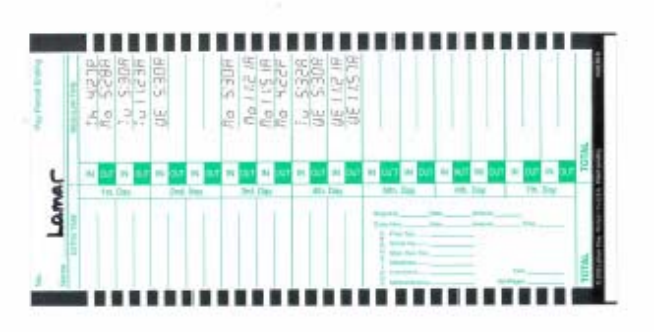

Figure 8 *Print sample of time card*

Other potential applications

This printhead was developed for a specific application for a defined product, but there are potentials to be used for devices which will require very simple and reliable thermal printing. The limitation is that the printing fonts and spacing are fixed, but some applications may not need such functions. The printhead was designed for direct thermal application, but it can be adopted for thermal transfer printing applications with transfer ribbon mechanism. Potential uses can be:

- Date code printing
- Time stamp
- Production lot printing
- Entry/exit marking
- Fix field index/id # printing
- Small hand-held printing device

Conclusion

This was the "back-to-future" printhead as new application merged to utilize the old concept. Although the current line-type thermal printheads in general thermal printing applications will not be replaced by the segmented multi-digit printheads, there may be a niche potential application where clean, quiet printing in a fixed format is desirable.

References

[1] Jules H. Gilder, "Thermal printer: Hot challenger to the 'flying hammer' method," Electronic Design, April 13, 1972 pgs. 26 - 27.

[2] Hideo Taniguchi, "Print head with heated printing type" (title translated) Japanese Patent Sho 56-31046 March 26, 1981

[3] Hideo Taniguchi, "Thermal print head for direct thermal printing" (title translated) Japanese Patent Sho 48-99733 November 24, 1973

Author Biography

Before founding HIT Devices Ltd., in Kyoto, Japan, Hideo Taniguchi worked for ROHM Co., Ltd. for over 40 years where he was responsible for the products including items relevant to printing industry like thermal printheads (printhead with partial glaze layer, development / implementation of driver ICs on substrate for printhead) and development/mass-production of LED printhead. He received his BS from Ritsumeikan University in Kyoto (in the field of Applied Chemistry) with additional study in Electrical Engineering.

Ellery W. Potash, MSEE earned degrees in Electrical Engineering / Computer Science and Systems Science from the Polytechnic Institute of New York. In his career, Mr. Potash has designed numerous Microprocessor-based products for military, industrial and consumer applications. His management experience includes executive posts in both manufacturing and consulting enterprises. As Sr. Engineer for Lathem Time Corp., Mr. Potash has designed a variety of commercial products that measure, track and record time; most recently, an Employee Time Clock incorporating a unique thermal print head design (patents pending)

Jiro Oi works for HIT Devices Ltd., a Kyoto-based electronic component manufacturer. Native of Hokkaido, Japan now he resides in Brentwood, Tennessee. Prior to joining HIT Devices, he had been with Rohm Co. Ltd. for more than 15 years in the field of thermal printheads and other electronic components. He received his BSEE from California Polytechnic State University in San Luis Obispo, California and MBA from Thunderbird School of Global Management in Glendale, Arizona.