KODAK PROFESSIONAL ML-500

Digital Photo Print System

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Abstract

A new mid-volume photo printing solution using thermal dye sublimation with multiple printheads will be discussed. Performance and features will be reviewed, and comparisons will be made to other printing solutions. Several new design challenges presented by the multihead architecture will be reviewed, as will the solutions provided through integration of hardware, media, and software.

Introduction

For more than a decade, thermal dye sublimation printers have provided high-quality and industry-accepted solutions for digital pictorial hard copy output. Thermal printers based on dye sublimation technology currently provide digital printing solutions for consumer, professional, commercial, entertainment, and government imaging applications. While dye sub printers have always been fast enough for lower volume applications (much faster, in fact, than comparable inkjet solutions giving equivalent image quality and durability), they have never been able to provide productivity suitable for higher volume printing. In all such applications, the traditional thermal printer engine is limited in its productivity by the need to pass a sheet of dye-receiving media under a single printhead up to four times in order to transfer the dyes and overlaminate coating. In this traditional single printhead architecture, much time is wasted picking a sheet of media from the paper supply, staging that single sheet for printing, rewinding the media between printing passes, and advancing the patch-coated ribbon to the next color panel. The ML-500 system breaks this paradigm by eliminating all of these steps.

A thermal printer configured with in-line multiple printheads can create high-quality prints in a single pass operation. This approach provides dramatic improvements in throughput, creating a thermal printing solution for productive applications.

Printer Architecture

Conventional thermal printers employ a single printhead to transfer multiple colors to a sheet of receiving media in a stepwise fashion.

Figure 1. Kodak Professional ML-500 Digital photo print system

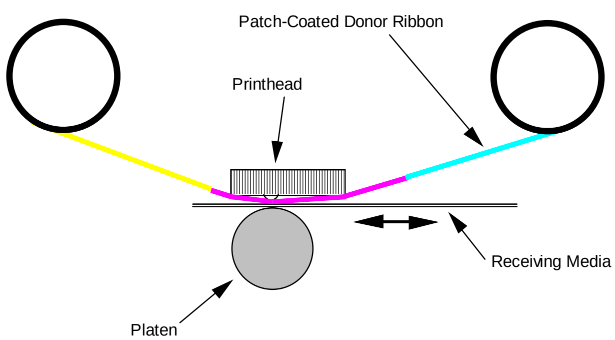

Figure 2. Conventional single printhead architecture

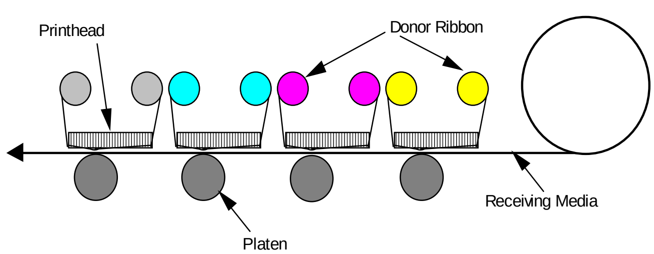

Figure 3. ML-500 digital photo print system architecture

The ML-500 system printer is based on the use of four printheads simultaneously printing on one continuous length of media. Each printhead is dedicated to one color or to the overlaminate application.

It is important to recognize that this idea is not new. The multihead architecture has been implemented before in other thermal transfer printers. Earlier products, however, were generally not aimed at high-quality photographic output. Others have applied this approach to the printing of labels, charts, signs, posters, and novelty items–applications where the image quality requirements are low. Most previous implementations were built for binary transfer processes such as wax or wax/resin transfer. The ML-500 system applies the idea for the first time to the creation of true photographic quality prints.

Applications & Markets

Market opportunities most suitable for the ML-500 system are in applications that can benefit from local, high-speed, mid-volume printing of photographic output, and/or applications that depend on on-demand photographic output in non-stationary and adverse-condition environments. The system is well suited to decentralized printing of school pictures, sports team photos, and any other portrait application that could benefit from more immediate delivery of proofs or final packages. The ML-500 system will provide a low-cost entry point for larger studios and small labs looking for the simplicity of a dry, digital workflow. Initial marketing will focus on:

- *Digital Photo Studios*
- *Small Labs*
- *Event Photography*
- *Government and Law Enforcement*

Features & Specifications

The ML-500 system consists of the printer, media, and host software and drivers. Table 1 summarizes the system features.

Table 1. ML-500 System Specifications

ML-500 system specification summary	
Steady State Print Rate	270 (8 x 10/h)
	540 (5 x 7/h)
	900 (4 x 6/h)
Paper Width	8.5 inches
Max Image Size	8.5 inches x any length
Media Types	Reflective Photo Paper
	Donor Y,M,C + Laminate
Print Surface Options	Glossy & Matte Laminate
Media Load Capacity	500 feet (donor and receiver)
Cutter	Integral one axis, automatic
Footprint (H x W x D)	22 x 17 x 26 inches
Weight	Approx. 110 lb
System Site Requirements	100-240 VAC/50-60 Hz/1000 W
Digital Interface	IEEE 1394 (Firewire)
Host Software Provided	User Utility & Set-up Application
	Color Calibration Application
	Service Diagnostics Application
	Hot Folder Print Server Application
	Windows Printer Drivers

Design Approach

The goal of the design team was to provide a small, transportable photo printing system that would fill a space between the small, low-volume cut sheet printers used by independent photographers and studios and the high-productivity, traditional AgX printers employed by centralized labs. In order to meet the perceived requirements of users in this space, several baseline constraints were imposed on the design:

- *The printer must have photographic image quality as good as existing Kodak thermal printers.*
- *The printer must provide at least 250 8 x 10's per hour.*
- *The printer must hold at least 500 feet of media.*
- *The printer must be easily transportable by two people.*
- *The printer must be small enough to mount in a standard equipment rack.*
- *The printer must run off a standard 110 Volt AC power outlet.*
- *The printer must be capable of continuous duty.*

The image quality was achieved through leverage of Kodak's existing thermal printing component technologies. The printheads, power supplies, media (both ribbon and paper), and printing algorithms are all based on proven technology already in use in other Kodak products. Each print station is essentially an independent printer with its own printhead, power supply, image chain, and real-time compensation algorithms. There is nearly zero cross-talk between the print stations.

The physical size and weight requirements were achieved by a tight arrangement of the print stations around the paper supply, combined with the sensible selection of components and materials.

Productivity, power draw, and duty rating requirements were simultaneously achieved through a program of thermal modeling and iterative design of the cooling and air management systems.

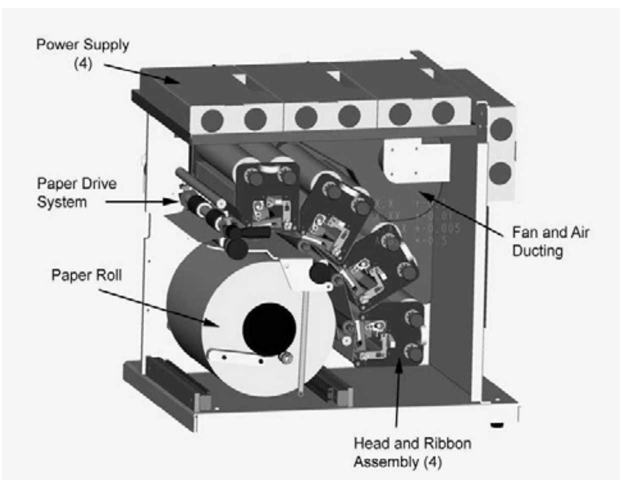

Figure 4. ML-500 system physical arrangement

Design Challenges

During the design of the ML-500 system printer, many design challenges and trade-off decisions were presented. Some of these challenges were common to the design of a single-head printer, and some were new and unique to the multiple-head architecture. A brief discussion of several of those new challenges follows:

Media Waste

A critical requirement of any thermal printer is the maintenance of uniform paper speed during printing. Even small variations in paper speed results in noticeable banding artifacts in the finished print. This requirement is always a challenge in the design of a single-head system, but it is even more difficult in a multiple-head system–the paper speed must be uniform and *identical* at each print station. In order to ensure the best paper motion uniformity, a single-drive roller was implemented downstream from the last print station to *pull* the paper through the system. This system has many advantages by keeping the printer compact, less complex, and easier to maintain. The downside of this pull-through architecture is that media is wasted every time printing is interrupted. As the last print in a print run is imaged, it needs to pass under each of the four printheads and out the front of the printer. When the last print is requested (i.e., there are no more images queued for printing), blank media must be advanced until the last image is complete. At this point, there is unprinted media threaded through the system. When printing is begun again, the unprinted media will be delivered out of the printer as waste, as the new images are printed, beginning at the first print station.

The best way to minimize this media waste is to make the distance from the first printhead to the drive roller as small as possible. The ML-500 system minimizes the media waste by arranging the four print stations in an arc, keeping them as close together as possible. In addition, the print server software provided with the printer provides queue management options that allow the user to hold back jobs until a certain minimum queue size is reached.

Cooling

Traditional single printhead thermal printers can take advantage of the large amount of non-printing time during a print cycle to allow the printhead to cool down. Whenever the media is being repositioned in preparation for a printing pass, the printhead is idle and can be cooled relatively easily. Most single-head printers also employ fans to cool the head while printing. In a continuous printing device like the ML-500 system, there is no idle time at all to allow the heads to cool. Therefore, the new design challenge was to design an air management system that would remove enough heat to allow the heads to print continuously. A system consisting of a single fan connected (via a plenum and ducting) to each print station was designed and implemented. Finite element models of the heat transfer behavior were used throughout the design phases to ensure the cooling capability.

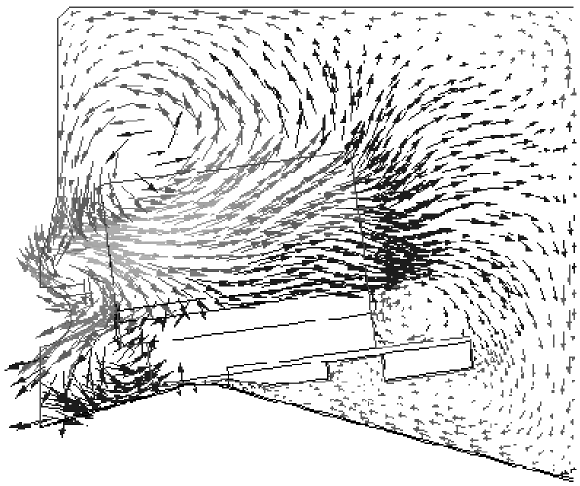

Figure 5. End view of one print station showing air speed vectors

Color Registration

Pixels in a dye sub-thermal print are formed by combining varying amounts of dye from the ribbon in a true contone fashion. The colors are printed directly on top of each other to build up a single dot of the desired color. The challenge, therefore, is to make sure the dots are placed precisely on top of each other during each color pass. If the colors are not positioned correctly (misregistered), sharp edges become muddy and color fringes appear around printed structure.

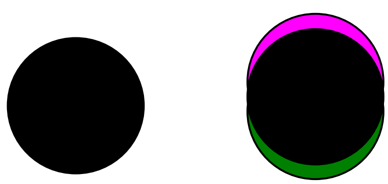

Figure 6. Color registration example

In a single-head system, the design challenge is to precisely position the sheet of paper for each print pass. This implies maintaining accurate positional control over the sheet during the print pass and during each rewind cycle. In a multiple-head system, the job becomes one of establishing precise alignment and location of the printheads relative to each other, and maintaining precise motion of the paper past the printheads. Because registration in the slow-scan direction (along the length of the paper) is established by precise timing of the arrival of print lines as they move from printhead to printhead, any variation in paper speed will impart dot placement errors, as will any variations in head position. The careful management of paper drive and back tension are required for consistent color registration in the slow-scan direction. Fast-scan (side-to-side) registration is managed by ensuring precise tracking of the paper as it moves through the printer. Slowly changing variations in the side-to-side position of the paper are less of a problem because the registration error of a particular dot will only be a function of the amount of paper wander that occurs between the first and last printhead. Registration in the ML-500 system printer is achieved through a combination of mechanical adjustments (to precisely set the alignment of the printheads) and software settings (to set the timing between print stations). Tools provided in the user utilities application allow simple adjustment of the station-to-station registration.

Printhead Uniformity

One critical component of image quality in thermal printers is the print density variation caused by pixel-to-pixel efficiency differences within a printhead. A typical printhead in a printer such as the ML-500 system has 2560 individually addressable resistive heater elements (pixels) spaced at 300 per inch. Ideally, each of these pixels will deliver precisely the same amount of heat when energized at the same level. In this ideal case, energizing all the pixels together with the same input signal produces a perfectly uniform flat field image. Unfortunately, normal variation in the printhead manufacturing processes produce heads with non-uniform pixel efficiencies. The result, in the printing example given above, is a flat field print with streaks. The more efficient pixels print darker and the less efficient pixels print lighter, creating correlated streaks, which are easily visible to the eye. In order to deal with this problem, printer manufacturers must either pay a premium for specially treated printheads that have been individually "trimmed" during the manufacturing process, or they must individually characterize the nonuniformities of each printhead and build a pixel-by-pixel correction capability into the printer image processing chain. In either case, the results are never perfect, and some level of streaking will usually be visible in critical images with large areas of constant neutral density.

In a single printhead printer, the streaks created by the head nonuniformity are the same for each color pass because the same printhead is used to print all the colors. The result, in a flat neutral density field, are streaks that are merely lighter or darker, with generally the same neutral color balance as the surrounding area. In a multiple printhead system, the colors are printed with dedicated printheads, each of which has a unique pattern of nonuniformity. The result is a pattern of colored streaks, rather than neutral streaks. If this effect is severe enough, the local color balance variations in the printed output may be enough to make color calibration difficult. To minimize this effect, the ML-500 system employs real-time compensation for the printhead nonuniformities. These compensations are based on custom characterizations of each printhead generated at the time of manufacture.

Conclusion

Thermal dye sublimation printers are capable of providing high-quality photographic output for a variety of applications. Their simplicity, size, robustness, and productivity have made them especially well suited to on-location print fulfillment and other relatively low-volume workflows. The ML-500 system maintains the positive features of dye sub-printing and adds dramatically improved productivity to provide a new option for higher volume digital workflows. Robust implementation of multiple-headed architecture based on experience with traditional design was key to the successful development of this printer.

Biography

David Coons is an Engineering manager for Eastman Kodak Company’s Thermal Printer Design Group. He holds a Bachelor’s degree in Mechanical Engineering and a Masters degree in Electrical Engineering, both from Rochester Institute of Technology. He has worked at Kodak for 17 years.