Electrophotographic Color Printer Engine
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Abstract
We developed a tandem type (serial arrangement type) full color printer engine, which is suitable for high-speed printing, utilizing the compact features of an LED (Light Emitting Diode) head. Our development included a position adjustment system to insure the accuracy of a printing position, paper feeding mechanism, electrophotographic process and fusing technology including toner to insure color stability, a control circuit for driving multiple light sources and its electrophotographic process simultaneously, and firmware. As a result, we implemented a printing speed of 8 ppm, which is the fastest in the world for 600 dpi desktop type full color printer engines.

1. Introduction
Color documents used in offices are rapidly increasing because of its visual beauty and the rich volume of information that can be transferred. As the Internet environment and inkjet printers become popular, an environment to create color documents is easily becoming organized.

However, application fields are limited because the speed of full color printing is slow. The speed of electrophotographic color printers released from other companies in the last year is 4 pages / minute (ppm) (A4 size paper), which is not sufficient for actual use in offices.

As a result we decided to develop a tandem type color printer horizontally arranging 4 independent light sources and an image drum unit (ID) suitable for high-speed operation, which can print 4 colors simultaneously with one paper feed. This system can fully utilize compactness and high reliability, which are the biggest advantages of our LED heads.

A disadvantage of the tandem type is that equipment size is large, but we solved this by developing a compact ID. Another disadvantage is that assuring positioning accuracy is difficult, but this was solved by developing a feeding belt and compensation method. Considering the simplicity of exchanging not only such consumables as toner and ID, but also a feeding belt and fixing unit by the user, we implemented a maintenance free system and developed an engine that can withstand actual operations for office use.

2. Features of tandem method
2.1 Comparison of electrophotographic color printing methods
Four major methods are now used for electrophotographic color printers, as shown in Table 1. This section briefly describes the configuration and features of these methods.

1. Tandem method: Four process units that correspond to 4 color toner images are lined up, transferring toner images sequentially to paper which is attached to the feeding belt by static electricity and fed by the belt. The structure is large and the positioning of the 4 process units is a problem, but the biggest feature is that this method prints 4 colors simultaneously at high-speed with a 1 feed paper operation.

2. Intermediate transfer body method: 4 color toner images are first created on a drum or belt shaped intermediate transfer body, then the images are transferred to paper. Paper selection is flexible but maintaining image quality is difficult because the transfer process must be performed twice.

3. Batch multi-development method: 4 color toner images are successively multi-developed directly on the image drum, and are then transferred to paper in one process. Since a transfer body is unnecessary, this system has the simplest structure. Downsizing and decreasing cost are possible, and color combining is also simpler than other systems, but images must be charged, exposed and developed from the toner developed on the image drum, and

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color reproduction / gradation control is difficult due to interference among toners.

4. Transfer drum method: Paper is wound around the transfer drum, and Y (yellow), M (magenta), C (cyan) and K (black) of the 4 color toner images are sequentially multi-transferred directly to paper. Color combining is easy but thick paper cannot be handled.

### 2.2 Adoption of tandem method

We adopted the tandem method due to the following (1) - (3) reasons for our new development.

1. The methods described in Section 2.1, other than the tandem method, can provide only 1 page of color printing per 4 times of the print process, which makes the printing speed 1/4 that of monochrome printing. In the case of OHP (over head projector) film, in particular, projected colors look darker unless toner is completely fused. So in order to completely fuse toner, the fusing speed of OHP film is slowed down to 1 - 2 ppm, while for plain paper the speed is 2 - 4 ppm. The tandem method can complete color printing with one printing process, so the printing speed can be 4 times faster than other methods. In the future, high printing speeds will definitely be demanded for color printing, therefore the tandem method will be a major color printing method.

2. For the tandem method, such processes as exposure, development and transfer can be independently designed for each of the 4 colors. Since flexibility of process design is higher than other systems, the technology accumulated for monochrome printers can be used.

3. Since viscosity at fusing is low, images can be multi-transferred contacting paper, using polyester color toner which has a wide color reproduction range. This makes color reproducibility good, and transfer efficiency is also good, which decreases the quantity of wasted toner.

### 2.3 Technology for solving problems of tandem method

To adopt the tandem method, however, there remain some shortcomings to be solved.

1. Keeping printer size small

   Figure 1 shows the configuration of a tandem printer when an LED head is used. As is shown, if 4 lasers are used for the optical writing system, the printer size increases and reliability drops. If compact LED heads, an Okidata original development, are used, then a desktop size tandem color printer can be implemented, avoiding a complicated mechanism.

2. Color combining accuracy

   Alignment of the ID units is too complicated to adjust mechanically, so the ID unit positions are adjusted by memory control in 3 directions: main scanning direction, sub-scanning direction and diagonal direction, while exposure by the LED heads is executed.
3. Configuration of mechanical component

To fully utilize the features of the tandem system, we adopted the following configuration.

3.1 Implementing color combining system

1. Adoption of feeding belt

In order to transfer each color image from the 4 IDs without any deviation when the target medium is being fed, the medium is attached to the semiconductive feeding belt by electrostatic suction, and images in each color are transferred to the medium at a constant feeding speed. At the same time, we developed a seamless feeding belt, which makes continuous printing of the medium at high-speed possible. We also adopted a method to give a certain amount of slack to the medium by a resist roller, so that a change of feeding speed, when the feeding belt is feeding the medium, does not cause a shift in the medium. Because of this, a color shift can be prevented. Also to minimize a feeding accuracy variation caused by the environment, we adopted a thin rubber roller for the drive roller of the feeding belt.

2. Maintaining positional accuracy of image drum against environmental changes

To control a positional shift of each ID in various environments, the frame is made of sheet metal which has very little dimensional change caused by the environment, and each ID is configured such that position is individually fixed.

3. High precision gear

Color combining accuracy was determined considering the image uniformity demanded from resolution limit and capability to identify local density changes by human eyes. For this, we adopted a gear with controlled decentering, and implemented image reproduction with no printing unevenness.

4. Prolonging life of ID

In tandem type color image printing, 4 IDs for Y, M, C and K are used. Therefore in single color printing, the IDs of the colors not used for printing are also operated without participating in actual printing. In this case, IDs perform printing operation without actual print data, and the color reproducibility of IDs gradually drops and the life of an ID that insures the specified level of an image becomes shorter due to the deterioration of the process component.

In Okidata’s tandem method, an ID not used for printing is elevated to the position where the feeding belt...
and medium do not contact, stopping the rotation operation, so as to prevent deterioration of the process components. When printing of paper ends, IDs are elevated and stopped to minimize an unnecessary operation, which prolongs the life of an ID and decreases the power consumption of the printer.

3.2 Fusing performance (uniformity of images)
1. Adoption of soft heat roller
We adopted a soft heat roller which has a rubber layer on its surface, since a uniform gloss is a very important parameter for color images, and because this roller also helps to clearly reproduce fine line images. We also adopted an oil roller which evenly supplies oil to the surface of the soft roller, implementing uniform images with high transparency for OHP film.

2. Adoption of oil roller
Oil must be supplied to assure the release performance of the soft roller from toner. We developed toner that requires very little oil, which made fusing possible with 1/5 - 1/10 the oil required for conventional color image fusing. This allowed us to adopt an oil roller system with a small oil capacity. As a result, a color image with high transparency was implemented for OHP film.

3.3 Maintaining high image quality and simplifying user maintenance
To easily maintain image reproducibility, we made the following 2 component blocks into units. As a result, user friendly maintenance was implemented.
1. Feeding belt unit
The transfer roller (ozone-less transfer), which transfers images on the image drum of the ID to the medium, and the feeding belt, which feeds the medium, deteriorate over time. Conventionally the usable period of the feeding belt and transfer roller is shorter than the life of the printer, so when the image reproduction status begins to deteriorate, each of these components must be replaced.
Okidata adopted a unit structured feeding belt so that when the image reproduction status changes, status can easily recover the original status by replacing the unit.

2. Fuser unit
A soft roller is used because uniform fusing performance is extremely important for color images, however the surface status of the soft roller deteriorates easily. Because of this we adopted a unit structure for the fusing section, so that when fusing uniformity begins to change, fusing can easily recover the initial status by replacing the unit.

3. Structure of printer
The basic mechanical structure is vertically divided into two sections. The top part can be opened or closed while hinged to the bottom part, and is comprised of a sheet metal frame and cover which functions as a face down eject stacker. In the sheet metal frame, LED heads are housed. When the top part is closed, each LED head is guided to the guide of IDs, and is setup at the specified position. In the bottom part, the fusing unit, feeding belt unit and IDs are installed, and the power supply, control component and drive system are built in. Since a straight path route was adopted, comprising a front feeder and face up stacker, OHP film and thick paper medium can be used.
The use of Okidata’s original compact LED heads made it possible to adopt a simple shell type open / close structure. As a result, an internal structure with a high user maintainability and low height printer was implemented.

4. Configuration of engine control section
The engine control section of this printer simultaneously processes the 4 colors of the color process in parallel. With this hardware configuration which is suitable for high-speed, an 8 ppm recording speed was implemented. We also improved the quality of full color images by including a compensation circuit for aligning 4 colors at high precision.

4.1 Hardware configuration
Figure 3 shows a block diagram of the engine control section of this printer. To decrease the size of hardware, one LSI and a general 8-bit CPU (MSM 65524) execute all engine control functions. The functions of the LSI are as follows.
1. Video interface
This function receives 4 colors (Y, M, C and K) of image data, which has been edited in the image generation section, at high-speed. The received image is temporarily stored in video memory.
2. LED head interface
This function reads print data from video memory and
transfers the data to the 4 lines of the LED heads. The 4 lines can control processing independently.

3. Color shift compensation circuit
Since 4 color print data is printed on paper combining 4 colors in 1 paper feed, the occurrence of a color shift due to mechanical factors is unavoidable. Therefore color shift is compensated for via video memory for 3 directions: main scanning direction, sub-scanning direction and diagonal direction.

4. Motor control circuit
This printer uses many stepping motors to feed paper, and to drive the belt, IDs, front feeder and fusing unit. By the LSI controlling these motors independently, 4 colors of color combining accuracy can be improved. Motors are controlled by hardware, so that load on the CPU is decreased.

5. High voltage power supply interface
A high voltage power supply is connected to 2ch of the serial interface. Output ON/OFF and voltage settings are programmable so that detailed printing process control is possible for each color.

6. General input/output port
This printer has a sensor input port for paper position, size detection and toner detection, and an output port for heater control and motor ON/OFF control.

4.2 Printing speed control
To support various printing media while assuring full color image quality, this printer has a 2-speed printing function. For plain paper printing, the printing speed is 8 ppm, and for OHP film and thick paper, the printing speed is 6 ppm.

Full color image quality and the transparency of light of OHP film, in particular, greatly depend on the fusing speed and fusing temperature. We therefore adopted an original control system and implemented a 6 ppm printing speed.

4.3 Printing control
Figure 4 is the general printing time chart of this printer. The color printing sequence is described below.
1. Paper is loaded from cassette.
2. Paper is fed by the feeding belt.
3. Yellow (Y) is printed.
4. Magenta (M) is printed.
5. Cyan (C) is printed.
6. Black (K) is printed.
7. Toner on the paper is fused and ejected.

In the case of continuous printing, the above operation is seamlessly repeated, and an 8 ppm printing speed is implemented.

4.4 Power supply section
The power supply of this printer is divided into a high voltage power supply for process control, and a low voltage power supply for the logic circuit and motor drive circuit. The low voltage power supply, which adopted a resonant switching system, has good energy conversion efficiency, and the power consumption during standby status is low. When the power save function of this printer is executed, this printer clears the International Energy Star Program standard because of its energy saving design. The high voltage power supply, which adopted a dedicated LSI, is compact and has a multi-channel output. Output voltage control can be programmed for each color independently.

5. Configuration of firmware
Figure 5 shows the firmware flow chart of this printer.

This firmware implements full color printing by lighting 4 LED heads (4 colors) via the video interface according to 4 color (Y, M, C, K) image data which was edited by the image generation section. A command from the image generation section is analyzed by the main control LSI, and the image control command is sent to the video interface, LSI, and various motors.
The generation section is received by the interface control program, is then analyzed by the command analysis program, and is notified to the main control program. When a print request is sent from the image generation section, the main control program executes each function using each of the following programs: motor control program, heater control program, high voltage control program for IDs, fan motor control program, and option tray control program (when a paper feed from the optional tray is specified). During printing, the jam monitoring program for paper feeding, the remaining toner monitoring program, and the EEPROM control program for monitoring the life of each consumable execute the respective program.

We improved the independency of each control program, including the main control program, to support high-speed full color printing. As a result, each control program has been simplified. Instructions from the main control program to each control program is sent as a message, which insures the independence of each control program. High-speed processing is implemented because each one of the simplified control programs operates only the necessary operation when instructed.

### 6. Performance

Table 2 shows the performance of this engine.

### 7. Conclusion

We developed the world’s top level color engine utilizing LED technology that we have been accumulating for many years. In the future, we will continuously develop engines aiming at faster and higher quality printing.

### 8. Reference