Controller Hardware Technology

In general, color page printers consist of two sections. The first section is the engine section, which consists of the mechanical section that includes the electrophotographic process and the mechanical control section. The second section is the controller section that controls the overall printer, including communication with the host. In this article, we would like to discuss this second section: the controller section.

Up until now, controllers for medium-speed to high-speed color page printers with an output of 20 PPM or more were expected to be fast. Therefore, either general-purpose or dedicated workstations had been used as printer controllers. Consequently, the cost of the controller alone was on the order of several million yen, which was not something that could easily be introduced for typical office use. In order to provide high-speed color page printers that can be used in the office, it becomes necessary to develop a dedicated color controller that can be embedded inside the printers, exhibits performance superior to that of a workstation, and sells for a reasonable price.

Electrophotographic color printing is performed by overlapping four colors: black (K), yellow (Y), magenta (M), and cyan (C). Oki Data’s color page printers employ Single Pass Color™ technology that uses a series of our digital LED heads. With this technology, one image formation unit for each of the four colors is arranged in series along the paper travel path, and the colors are directly overlapped onto the printing medium. The printing speed is the same as the printing speed of each color’s image formation unit. From the perspective of the controller, it is being required to simultaneously control four colors and generate video output signals.

Figure 1 is a block diagram of the color page printer controller. Also, there are four technology requirements for the controller being used.

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* Oki Data Corp., Controller Software Center, Controller Development Department, Team Leader.
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* 1 Single Pass Color™ is a trademark of Oki Data Corp.
a. Must have a fast, general-purpose interface function. Must realize a basic interface for an IEEE1284 parallel interface or a network interface (NIC). Using PCI (Peripheral Component Interconnect) for the interface between the controller and the network card makes it possible to secure fast speed and provide generality, realizing expandability to a variety of interfaces.
b. Must have a fast processor (generally a CPU). Connecting a level 2 cache to a high-performance CPU equivalent to a PowerPC® 750 effectively uses the processor performance and realizes high controller performance.
c. Must have fast memory and sufficient memory capacity expandability. Must use fast DRAM such as SDRAM (Synchronous Dynamic Random Access Memory).
d. Must be fast, compact, and have low power consumption. Fast, multifunctional hardware functions must be put onto LSIs, and compactness and low power consumption must be realized. Especially color matching, multi-value color, binary data compression/expansion, and image processing such as error diffusion processing and dithering must be performed by a dedicated LSI.

As described above, the controller hardware is expected to have high performance. It must also be compact in size and provided at a low cost. At this point, several things become necessary: the development of a highly integrated, fast custom LSI, accelerated design technology for operating a CPU, level 2 cache, and main memory at high speed. Furthermore, simulation of every kind of delay and waveform is an absolute must.

Controller Software Technology

With high-speed, high-performance printers, in order to ensure independence from the device specifications of each printer and to reduce the load of the host computer, the printing data is described using PostScript®, PCL, or other page description language (PDL). The controller software must quickly interpret and execute this page description language to get the maximum printing speed from the engine section.

1. Basic structure of the controller software

The controller software performs many functions. One of them is to translate printing data (jobs) while expanding it into a data format that can be output as video in 1-page units (hereinafter simply referred to as “video data”). Another one is to transmit this video data to the engine section along with the control command. This controller software controls the printing processing of the entire device.

Recently however, a wide variety of functions are being demanded. Examples are functions for printing when connected to digital home electronics devices such as digital cameras and scanners, job spooling using an HDD (Hard Disk Drive) built into the printer, and collating. Also, printers shared on networks are expected to support each type of communication protocol and remote monitoring function. The controller software takes additional requests of these new functions into account and realizes a hierarchical structure that emphasizes function expandability. (Figure 2)

The OS (Operating System) layer consists of a real time OS (kernel), device drivers, file system, and standard library. It also conceals the hardware (controller and engine section) differences. The OS layer uses VxWorks®, a widely used software package, as the embedded real-time OS. Therefore, it is easy to use the CPU that is most suitable for the required printer performance and cost, and to take advantage of the plentiful tools and libraries available for VxWorks®.

Also, as many of the following PDL-specific common functions as possible should be provided in the printing control layer in order to minimize the number of functions mounted in the PDL layer and facilitate the addition or removal of PDL.

- Receive printing data from each type of communication device
- Engine section printing sequence control and synchronized transmission of video data
- Reporting warnings or errors relating to the remaining lifetime of consumables such as toner or image formation units, paper jams, empty paper trays, and size mismatches
- Use operator panel or network management utility to refer to/change printer status displays or menus (each parameter)
- Job spooling, collated printing, authentication printing, confirmation printing
- Distribution to the appropriate PDL processing system recognized by PDL that describes the printing data

In order to realize the previously mentioned variety of functions, the printing control layer uses an object-oriented design methodology and language to realize a structure that emphasizes reusability, expandability, and model independence. Also, by clearly separating model

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*2 Power PC is a registered trademark of International Business Machines Corp.
*3 PostScript is a registered trademark of Adobe Systems, Inc.
*4 VxWorks is a registered trademark of Wind River Systems, Inc.
independent parts from model dependent parts and minimizing the model dependent parts, we have made it easier to simultaneously develop multiple models and to transplant them to new models.

2. Accelerating printing by overlapping jobs

The PDL layer translates and compiles printing data, generates data in page units, then transfers the data to the printing control layer. The printing control layer transmits this page unit video data to the engine section then invokes the printing process. In order to accelerate the entire printer, when the translation/compilation process of the current printing data (job) is complete, it is preferable to begin processing the next job without waiting for printing in the engine section to end (job overlapping).

The printing control layer therefore makes it possible to generalize memory management between PDL layers and start PDL processing of the next job without waiting for printing of the current job to complete. This is possible even if the current job and the next job have different PDLs. Therefore, it is possible to continuously print at top engine performance without losing speed at the job boundaries (PDL switching) even if different PDL jobs are consecutively transmitted from the host computer.

3. Accelerating color image processing

Generally, a large amount of data must be handled in order to perform image processing such as data compression and expansion, image enlargement and reduction, half tones, and color matching. This color image processing becomes a bottleneck to the processing speed in the case of the PDL processing system. That is why the controller, by using an LSI dedicated to such color image processing, realizes accelerated printing speed. In addition, the PDL processing system is designed to maximally juxtapose software processing performed by the CPU and hardware processing performed by the LSI. This is accomplished by dividing one page into multiple bands and using a pipelining methodology to process the compilation processing in band units (Figure 3).

4. Concealing using streams

Streams and the interface standardization are concealing differences between each type of communication device and protocol used to receive printing data from the host computer.

Concealing in streams makes it possible for the printing control layer and PDL layer processing system to read out the printing data without having to know which communication device or protocol is receiving the printing data. Streaming this data makes it possible to even process data for local printing such as for demonstration pages and menu maps in a similar manner to reception data from the host computer.

Driver and Network Technology

1. Color adjusting functionality is important for color page printer drivers. Color matching systems are used when printing in color in order to approximate the colors on PC screens and the colors output by printers during printing. Our printer defaults to the optimal color matching system we originally developed for it. Depending on the user settings, our printer will also support system color matching such as ICM for Windows and Apple’s ColorSync. Our printer uses device profiles to respond to applications that use our original color matching system. Also, it is possible to use the half tone type settings or color adjustment settings to change the colors during printing. Furthermore, the half tone adjustment utilities (different software than the driver) make gamma adjustments of the four colors (cyan, magenta, yellow, black) possible.

2. Various printing functions

A variety of printing functions is available for printer drivers. Examples are the electronic collating function, confirmation printing function, authentication printing function, custom defined paper function, form overlay

![Figure 3: Paralleling the Color Image Processing](image)

![Figure 4: Concealing Using Streams](image)
printing function, multipage printing function, and booklet printing function.

We also provide a storage device manager for managing memory devices such as the HDD or flash memory built into the printer. This makes it easy to register, refer to, or delete form data.

3. Network direct printing function
The roles of a network utility that supports operation management of printing or the printer itself are much more important for shared printers in a network environment. One such role is that of an LPR (Line Printer Remote) utility that can directly specify an IP address and print without any print server. This LPR utility provides functions such as checking the printer status, downloading files (print jobs), and checking print jobs that have been spooled to LPR. This makes it easy to check the progress of a print job on the network from one’s own PC. Also, if an alternate printer is specified in advance, it is possible to automatically switch to the alternate printer if the default printer is either in use or is unable to print due to an error that occurred (load distribution).

Previously, there were situations in which LPR printing could not be performed since the IP address of the printer right on one’s desk could not be identified even after asking the network administrator for the printer IP address and looking for the ledger. We added the network search function to solve this problem. This function makes it possible to immediately perform LPR printing if search and display printers within a specific area are searched, displayed, and a printer is selected.

4. Monitoring function over a network
A network administration utility is also important to centrally monitor for printers that have run out of paper, paper jams, the lifetime of consumables such as toner, and hardware errors.

Even if special software is not installed, a Web browser on a host computer such as a PC can be used to access the Web server built into the printer to display the printer status, display the remaining amount of consumable such as toner, and make any necessary setting. It is also possible to set conditions to the printer and receive notification via e-mail each time that the applicable state (warning or error) occurs.

5. Print job accounting, operation management function
When managing network printers within an enterprise, it is important to not just monitor the state of each printer and distribute the printing load, but to manage operating costs as well. For example, managing usage restrictions such as the usage rate or load factor of each printer, the total number of pages printed per user (department or individual person), the number of printed pages, access to specific printers, color printing, and the printing medium (OHP or special paper).

An accounting operation management utility used for such an objective is required to have functions to perform the following analyses or generate the following reports. This is done by first fetching the print history (for example, recording the user ID, color print and monochrome print page count, and the medium used for each print job) retained in each printer. Then, compiling the history and converting it into a database on a print job management server. Finally, analyzing the history.

• Usage status and load factor of each printer at regular intervals
• Tabulate the number of pages printed and the cost of consumable items within a specific period by department and by individual.
• Setting usage restrictions for each user, and either sending a warning to user or prohibiting copying.