New Concept for Image Quality Control in B/W and Full Color Production Printing

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Abstract

Digital color production requires tight process control in order to achieve precise and consistent color reproduction – over run length, from job to job and between different print systems. The Océ Colorstream 10000 introduces a sophisticated concept of nested control loops which will be discussed in detail.

Introduction

There are two ways to create consistency and color fidelity using a digital color production printer: Freeze all boundary conditions like the climate, the coverage and the paper, or monitor the output and adjust the printer to the actual situation.

The control concept of the CS 10000 is designed to keep the output consistent with the paper and climate changing. To assure this a set of nested internal and external controls are using the input of several sensors. This sensor data are the input for independent regulation algorithms like the internal density and raster regulator.

In addition to this the CS 10000 has the new and unique ability to adapt the printing data online according to color measurements on the paper during the printing process.

The CS 10000

The CS 10000 (see Figure 1), which is based on the VS9000 [5] is designed as a high speed and high quality color printer. Due to its concept of collecting color on a transfer belt it is scalable in print modes from b/w (800 A4 images/min) to full color CMYK (170 A4 images/min). It has a dual engine architecture with single pass paper transfer and radiation fusing. The color control concept described in this article is applicable for all printing modes.

Overview

In Figure 1 the nested internal and external control loops of the CS 10000 color control are shown. The interference of the internal and external full tone control is designed in a way, that the external control adds corrections to the internal regulator which are necessary through paper characteristics or climate changes. The

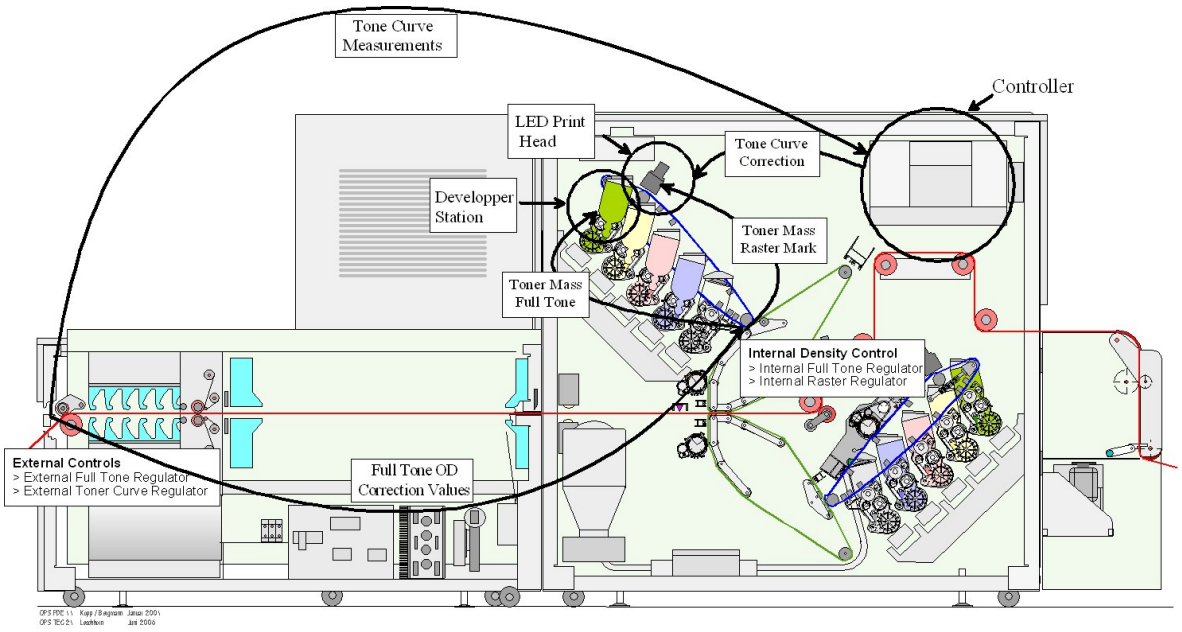

***Figure 1**. Overview of nested control loops and regulators with their impact on the print data of the Océ ColorStream (CS) 10000*

external tone curve control directly affects the screening process in the controller, while the internal raster regulator keeps the basic dot size stable by adapting the discharge level of the photo conductor.

Internal Density Control

The main color stabilization is done by the internal density control, consisting of the full tone density regulator and the raster regulator. This is done for every color.

The internal density control is reading the toner mass in two different marks using a capacitive sensor.

The toner mass in the full tone mark is the input for the internal density regulator that adapts the toner which is offered by the developer station for consistent full tone coloring.

The internal raster regulator is manipulating the discharge level via the light energy and thus, the dot size according to the toner mass in a raster mark to regulate raster OD and line thickness. To prevent misreadings of the raster mark, the development process is designed to keep the toner layer thickness even in dots and lines

So changes in the toner mass of the raster mark always result in changes of the dot size.

Together with the half tone calibration this is the basis for color stability.

External Controls

The external control is reading a special color control patch pattern (see chapter "The color control patch pattern") on the paper to detect and react on changes to the color appearance caused by the paper characteristic or the climate.

There are two external controls, the full tone regulator and the tone curve regulator. To understand how they work it needs a closer look at the control pattern and on the way the print and sensor data is processed by the color controller.

The external color control can be switched off by the operator so two control modes are possible:

- Online color control

For the online color control the external regulators are constantly measuring and, if necessary adapting the printer to assure the highest consistency and color fidelity.

- Printer adjustment

The printer adjustment mode can be used as a short printer calibration and can be initiated by the operator It can be useful, when the customer does not want the control patch pattern to appear on his output.

By simply printing the patterns without data the printer will get correction data for its color controls and store them for the next print runs until the next control patterns are printed.

The color control patch pattern

The color control patch pattern (see Figure 2) is printed on the left edge of the paper (see Figure 3) for every color and read by a densitometry sensor with a polarization filter.

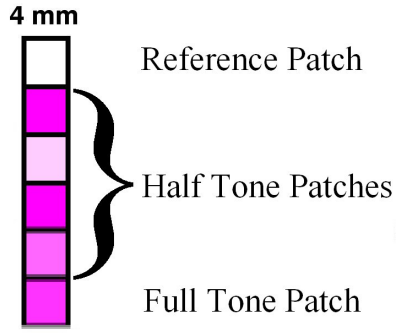

***Figure 2**. Example Patch pattern for the external color control*

The pattern is 4 mm wide and 24 mm long, so each patch is 4 mm by 4 mm. Being in 4 color mode the whole patterns are 84 mm long, as the reference patch is only needed once. The printing data is shifted automatically to prevent interference with the control pattern.

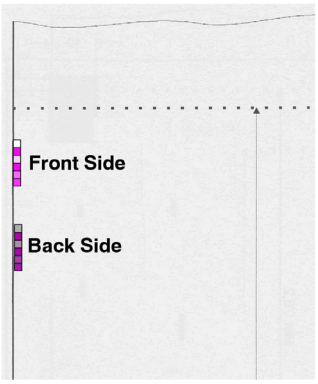

***Figure 3**. Position of control pattern on paper, arrow shows paper run direction*

For each color the pattern looks identically. The first color contains an additional reference patch for the paper white measurement, since the sensor readings are relative.

The next first four patches are half tone patches with a 20%, 60%, 80% and 95% raster for the tone curve regulator.

The last patch is a full tone for the external full tone regulator.

The patches are processed by the controller the same way the print data is. This way changes in the raster process or the calibration can be detected by the external sensor and the pattern shows the same behavior as the rest of the output in terms of full tone and raster density.

External Full Tone Regulator

The external full tone regulator creates correction values for the internal full tone control (see chapter "Internal density control") by measuring the full tone patch on the paper.

The external full tone control is prerequisite for the tone curve regulator.

External Tone Curve Control

To understand the external tone curve control it is important to have a look at the rasterizing process of the CS 10000 (see Figure 5). The printing data is processed online during the printing process in mainly two steps.

Step 1: The data is split in the CMYK color planes and rasterized by taking into account the tone curve and color profiles provide with the data, but also tone curve changes made by the operator, that are included in a half tone mapping look up table. That means that the operator can online map a 40% halftone of the incoming data to a 50% halftone that is processed in the rasterization process.

Step2: This is the new feature! Now the data from the external tone curve measurements (the 20%, 60%, 80% and 95% halftone patches) comes in.

The actual tone curve is calculated with the Murray-Davis equation (Figure 4), so it is crucial to have the 100%/full tone stable.

$$A = \frac{1 - 10^{-DR}}{1 - 10^{-DV}} \cdot 100\%$$

A [%]	***Tonal value in percent***
DV	***measured OD in full tone***
DR	***measured OD in half tone***

Figure 4. *Murray Davis Equation to calculate the tonal values from half tone OD measurements*

With this measurements and a suitable curve fit the actual tone curve for each color can be calculated.

By comparing this with the ideal/desired tone curve, that was stored during the calibration process in the dither matrices, a correction value for every half tone of the tone curve is stored in a look up table.

Using this look up table the adequate tone curve can be selected from the dither matrices for the screening process to close the regulation loop of the external tone curve regulator.

Sensors and Algorithms

Océ decided to use a densitometric sensor especially for its proven color control functionality in web offset applications. In addition to that it is a very cost efficient solution.

In algorithms the main engineering effort was used to design the tone curve fit and the calculation of the correction look up table. For the curve fit there are boundary conditions to consider, like assuring steadiness between the 20%, 60%, 80% and 95% halftone patches and prevent edges and bends.

The human eye can resolve about 100 half tone

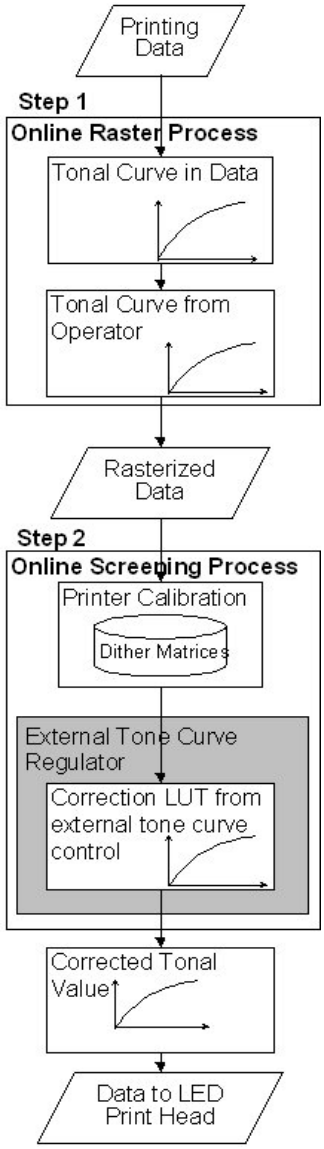

Figure 5*. Data Processing of the CS 10000 Color Controller*

levels, so the dither matrices for the screening process have to provide a sufficient number of printable halftones to be well above this threshold. This is only feasible by using the Multilevel function of the color controller which allows the LED print head to be triggered in 4 bit mode and to discharge the photo conductor in 16 energy levels.

As a result there are always more than 100 different half tones printable to assure step less and smooth half tone transitions.

Conclusion

The new and unique color control concept of the CS 10000 consequently uses the benefits of high speed online data processing and regulations and shows the potential in high speed color and b/w printing of Océs full color production printing flagship.

Acknowledgements

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Author Biography

Thomas Niethammer has studied mechanical Engineering at the "Technische Universität München" where he received his diploma 1997.In 1998 he joined Océ`s R&D division and works for the VS9000 and CS10000 project ever since in various areas, mainly concerning print quality and image development including the managing the Multilevel project.