COLOUR PRINTING—TODAY AND TOMORROW

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Abstract

Printing high quality colour at a low cost on plain paper may seem like a pipe-dream, but it is not. Over the past several years, a lot of R&D effort has been put in by various companies into colour printer technologies, and the next few years will certainly see some of these come to fruition as products. Colour printing is available now and will be commonplace tomorrow. The challenges and problems inherent in colour printing are discussed. The basic colour printing technologies, viz., dot matrix, ink-jet, thermal transfer, and laser are elaborated. The advent of ink-jet and thermal transfer printers are considered as instrumental in increasing the quality and at the same rate lowering the cost. The predominance of true colour laser printers and other technologies, giving photographic quality printing at desktop, is predicted.

Colour—an Exciting Trend in Printers Technology

Though the conventional laser printers have changed the quality of documents produced in today's office, the high-resolution black-and-white (B&W) output of these printers still lacks the critical dimension that is so highly coveted in presentation-oriented documents: colour. A sharp and well-designed B&W laser print-out quickly pales in comparison to a similar document in full colour. Colour is naturally appealing to the human eye; it is the most exciting trend in printer technology today.

Colour printers have been available for a few years, but high-quality, highly capable colour printers are a very recent phenomenon. High-quality PostScript -compatible colour printers priced as low as $7000, introduction of Tektronix's Phase III printer technology, Hewlett-Packard's 300 dpi ink-jet printer, and a number of other. developing technologies, have made quality colour printers practical for many offices. Although their increased complexity will keep colour printers from achieving price parity with their monochrome counterparts, lower prices will put colour printers on an increasing number of desktops.

Bringing colour printing to the desktop is not an easy task. There exist numerous challenges and problems inherent in colour printing.

Colour Printing—Challenges and Problems

The use of colour introduces many complex issues that do not apply to B&W printers. In each of a variety of applications, colour printers must meet different needs. When used for working copy, the prints must be easy to interpret, but high image quality is not critical. In contrast, for presentations employing transparencies, image quality is a key requirement. Finally, the use of colour prints as archival record dictates that the colours not fade with time.

Many factors influence the suitability of colour printers for these different applications. Among the key ones are: printer cost and speed, the cost of supplies, flexibility—the range of media that a printer can accept and whether it can produce graphics only or both graphics and text, and reliability. In addition, user-convenience features have a significant impact on the long-term acceptance of a colour output device. The most important factor however is the image quality. Today printers are capable of producing millions of colours on command, but the problem lies in matching these colours with what one sees on the screen or with the output of•the printers.

Primary Subtractive Colours

The printing industry uses primary subtractive colours—CMY (cyan, magenta, yellow) for colour printing. The subtractive primaries are created by subtracting a particular colour from the light reflected off a white page (i.e., cyan in the absence of red, magenta in the absence of green, and yellow in the absence of blue). The subtractive primaries combine to form the other colours in the printer's colour gamut. For example, a printer can combine the primary subtractive colours in equal amounts to generate the primary additive colours (i.e., magenta plus yellow gives red, yellow plus cyan forms green, and cyan plus magenta produces blue). Equal amounts of the subtractive colours combine to form black. When combined with other primary colours, this forms the CMYK (cyan, magenta, yellow, black) colour models, the standard four-colour model in the printing industry. Thus, under the CMYK colour model, these printers are capable of producing only seven colours (cyan, magenta, yellow, red, green, blue and black), not counting the paper background colour.

To create other dot colours, a printer must be able to mix varying amount of the primary colours to create each dot. Because most designs do not allow this, most colour printers use dithering to generate a wider spectrum of colours.

Dithering Around

At a distance, the human eye tends to combine the tiny printed dots in a given area into a composite image. Dithering takes advantage of this, and it tricks the eye into perceiving a single colour from a pattern of coloured dots. Conventional B&W laser printers use dithering to generate half-tones-images having a grey scale. Varying the ratio of black dots to the white paper background results in shades of grey. The dithering process breaks a printout into pixels made up of a matrix of dots. At a distance of a few inches, the eye cannot distinguish the dots; it merely preceives a level of grey.

This concept applies to colour printers as well. A colour pixel consists of an array of colour dots, ranging from a single dot to 64 (an 8 by 8 matrix) dots. The more dots there are, the greater the number of colour combinations that the printer can create. Because each dot can be any of the eight colours (including the white background), the colour gamut grows rapidly with increase in the number of dots per pixel. In a simple 2 by 2 matrix, each primary subtractive colour can have from 0 to 4 dots turned on, for a total of five-dot combinations. Because printers can overlay the matrix pattern of the primary colours on top of one another, the three primary subtractive colours combined can produce 125 (5 x 5 x 5) colour shades. This quickly increases to produce nearly 375,000 colours for an 8 by 8 dot matrix.

Colour Matching

Controlling the colours produced by colour printers is a growing concern. For low-end dot-matrix units, the colours follow no industry standards, and the printers stimulate the desired colours as best they can. Other colour printers attempt to follow colour standards established in the printing industry, but they still allow variation in the output. Because colours vary from monitor to monitor, it is not easy for a colour printer to support a wide variety of monitors. The problem is compounded by other issues. The colours on a given monitor can vary depending on the age of the monitor, the brightness and contrast settings, and even the amount of time the monitor has been used. A number of colour-printer manufacturers, most notably Tektronix and HP, put a lot of emphasis on monitor/printer colour matching. One can specify the type of monitor one has, and the printer will adjust all subsequent colour printouts according to the characteristics of the selected monitor.

Because colour printers combine or dither primary colours (using the CMYK colour model) to create their colour gamut, instead of using pure spot colours, printers use colour simulations to generate colours that match international standards. Even with colour standards in place, one can still get great variations in the accuracy of colour printers due to the numerous variables that remain, including paper colour and quality, equipment condition, screen-tint values and angles, ink quality, ink flow, colour registration, and the order in which the printer applies the primary colours to the page.

Colour Printing Technologies

Before colour computer terminals became generally available, **pen plotters**, which use computer—controlled motors to direct ink pens across a sheet of paper, were the primary vehicle for obtaining hard copy in colour. But with the introduction of affordable colour terminals, the users wanted to have colour prints of what they could display on their screen. Because pen plotters are slow and because the range of colours and shades they can generate is so limited, the printer manufacturers turned to other printing technologies to satisfy their needs. Today, there are dot-matrix printers, electostatic printers, laser printers, ink—jet printers and thermal transfer printers.

Colour Dot-matrix Printing

In a dot-matrix printer, the print head typically contains nine or 24 pins that strike a ribbon to create ink dots on the paper. The pattern of the dots defines characters or graphical images. Colour dot matrix printers work the same way, with the addition of a multicolour ribbon up or down to select a particular colour.

Unlike other colour printers, colour dot-matrix printers use four-colour ribbons, which incorporate red, blue, yellow, and black ink. The red, blue, and yellow colours are primary colours and they combine to form secondary colours (e.g., red plus blue yielded purple, yellow plus blue produced green, and red plus yellow resulted in orange). This is basically the approach used in colour dot-matrix printers, limiting their colour gamut to a few basic colours.

Colour dot-matrix printers represent the low end in colour printers, and they are often characterized by slow, noisy operation and often mediocre output quality. Some of the newer 24-pin models provide better output quality than earlier models, but their resolution and colour saturation remain poor in comparison with those of other colour-printer technologies. Still, there are a lot of colour dot-matrix printers in use because they are often adequate for generating economical in-house colour presentation materials. Some printer manufacturers, like Star Micronics, make all their new printers colour-capable, letting the user select either a black ribbon for standard monochrome output or a four-colour ribbon for colour printing.

Electrostatic Printing

The primary advantages of electrostatic printing over pen plotting are its improved speed, quiet operation, and suitability for unattended operation. Electrostatic plotters operate by passing dielectric paper under a fixed-page-width electrostatic head that consists of a line of individual styli. Voltage is selectively applied to the individual styli, placing a charge on the dielectric paper and creating a latest image. Then the paper passes through a bath of liquid toner, and the charged areas attract toner particles. This charging and toning process takes place several times; the toner bath is different for each colour. One advantage of electrostatic plotters is their high resolution output up to 400 dpi. Some plotters also have a lower-resolution mode for proof-reading.

Colour Laser Printing

At the high end of the colour—printing spectrum is colour laser printing—a plain paper technology. The printing process is conceptually similar to that of a B&W copier. Exposure to light creates an attraction on certain areas of photosensitive surface, which then attracts the toner. When the toner is transferred to paper and heated, the image is formed.

With monochrome laser printing, once the image meets the paper, the job is done; there is only one image to transfer. With colour laser printing, however, the process is more complicated. The printer must lay down each of the subtractive colours separately, and it must carefully align them to create the clean, crisp images that laser printing is known for.

In this process, a photo-conductor belt is charged and exposed to the laser. This electrostatic map of the image passes beneath each toner module. The toner, which is a charged powder, is attracted to some areas and repelled from areas of opposite charges, creating a powder image. In the copier, the original is 'imaged' through filters that are the complementary colours of the toners. The data enters the printer as colour planes, with the conversion to the subtractive primaries performed elsewhere. The primary colour images are developed sequentially on the photo-conductor belt and overlaid on the transfer belt to make one image. In one step, the assembled image is printed directly from the transfer belt to the paper. After the transfer, the belt engages a cleaning station to remove residual toner.

The *Canon's CLC 500* exists as a colour copier only. To use it as a printer, one must add an optimal Intelligent Processing Unit (IPU) The IPU expands the copier's memory capacity by 12 MB to 24 MB,, provides it with more complex image-editing capabilities, and allows interfacing with other electronic devices.

The *Colorocs CP 4007*, on the other hand, already contains everything required to interface with the computer. It also has a PostScript-compatible colour controller.

The method of laying down colours is similar between these two printers—dry toner forms a latent image to a surface where the colours are built up—but the means of putting the image to paper is very different. In addition, laser printing has come to stand for print quality, speed and low cost—at least on a per copy basis. But, the colour laser printers are big-time expensive, priced at any way between $ 30,000 and $ 65,000.

Ink-Jet Colour Printing

Dot-matrix and laser printing represent the two ends of the colour-printing spectrum. Between them are the ink-jet and thermal-transfer printing, which represent a compromise between the inferior output of dot matrix and the steep price of laser. Ink-jet technology provides the middle ground for colour output, with a low-to-moderate price tag, good colour rendition, and medium-to-high-resolution output. Ink-jet printers use the CMYK (cyan, magenta, yellow, black) or the CMY colour model to generate their output colours, with four liquid-ink cartridges to hold the coloured inks. Units cost from under $1000 to about $2500.

Most ink-jet printers print at a resolution of 180 dpi. Conventional ink-jet printers employ a technique known as drop-on-demand operation, whereby ink droplets are propelled from a nozzle when an electrical signal initiates the action. There are two different approaches in use for propelling the ink droplets: thermal and piezoelectric. Thermal ink-jet printers (or bubble jets) are the most common of the two approaches.

Thermal Ink-Jet

In the operation of a thermal ink-jet printer, a small amount of ink is present in each nozzle and is in contact with a resistive heating element near the outlet of the nozzle. When an electrical signal is applied to the heating element, a small amount of ink boils and begins to vapourize, creating an ink bubble. As the bubble expands, it pushes ink out of the nozzle and the ink is propelled onto the paper. The resistive heating element heats up quickly, expelling the ink droplet within one millisecond. As the ink droplet exits the nozzle, new ink from the cartridge replaces it.

Piezoelectric Ink Jet

The operation of the piezoelectric ink jet is similar to that of the thermal ink—jet. A small piezoelectric crystal is present in each nozzle outlet. An electrical signal applied to the crystal results in a small dimensional change that creates a pump-like action, pushing an ink droplet out of the nozzle and propelling it towards the paper. When the electrical signal is removed and the crystal relaxes, replacement ink enters in preparation for the next print—droplet operation.

Continuous Ink Jet

Another ink-jet technology is the continuous ink-jet technology, in which the printer generates a continuous stream of each primary colour, producing about one million microdots per second. Dots that are not intended for the paper are electrostatically charged and deflected into a gutter. The microdots are only about 15 micrometers in diameter, so multiple microdots are combined to form one dot of the printer's standard resolution (300-dpi). As the printer is able to vary the number of microdots of each primary colour applied to a dot, it can generate its entire colour gamut on each dot without dithering. At 300 dpi, the result is a near-photographic quality printout.

The Tektronix's new Phaser III PXi printer is a 300 dpi colour printer that incorporates PostScript level 2 and supports printouts of up to 11 by 17 inches. It prints not only on plain paper but on virtually any medium from thin tissue to heavy cover stock. Because the ink—jet technology does not require specially finished or coated paper, the Phaser III can print on various features of paper as well. It is priced at $9995.

Thermal-Transfer Colour Printing

Thermal-transfer technology is behind most high-end colour PostScript printers. It uses heat to transfer ink from a special ink sheet directly to a paper or a transparency film. These special ink sheets come in large rolls and have multiple-panels one for each of the three subtractive primary colours and sometimes for black-laid out in serial fashion. One of each of the colours is required to create a single full-colour image.

The ink-sheet fits between the thermal print head and the paper. The thermal print head typically has 300 heating elements per inch (depending on the printer's resolution). As an electric current fires these elements, they heat the ink sheets and melt the ink onto the paper. The serial order of the ink-sheet panel requires the paper to be passed at least three times beneath the heating elements—once for each ink panel—to create a full-colour image.

The factors that affect the quality of the colour rendering in this process are: (i) the alignment of the dot patterns on the paper, the registration; (ii) control over the heating elements; (iii) the ordered placement of dots in a pattern called halftoning; and (iv) the resolution of the bitmap image that the print head creates.

Seiko recently introduced the *ColourPrint PSX,* a PostScript-compatible thermal-transfer printer that features a fast 25-MHZ 960 processor; up to 34 MB of RAM-to-buffer input; and serial, parallel and AppleTalk ports. The fast processor and large buffer let the printer download and store data from the host very quickly, releasing the host for other tasks.

Dye-Diffusion Colour Printing

Unlike the colour-printing technologies that dither colours on the page to produce more than seven colours, dye-diffusion printing lets one print millions of different colours. The result is a near-photographic colour quality. A 300-dpi dye-diffusion thermal-transfer printer gives the same visual results as the 2500-dpi halftone printing process used in many glossy magazines.

In dye-diffusion printing, the dot is equivalent to a pixel. The printer controller applies variable voltages to each of the approximately 300 tiny resistors per inch in the print head (depending on the resolution of the printer). Each resistor, in turn, produces varying amounts of heat. Dye-diffusion technology uses a type of ink different from the ink used in thermal transfer. This ink (or dye) converts directly from a solid to a gas when heated-*dye sublimation*. The various intensities of heat regulate how much ink turns into gas and is applied to the paper, varying the density of the printed dot.

Dye-diffusion printers also use a specially coated paper that takes an active part in the printing process. This paper is much like photographic paper. It is treated with a base chemical agent that reacts with the acidic colourants to actually develop the image, as the colourant diffuses into the paper. An image created in this way has an enhanced durability as it physically resides in the paper, and not on it. The mechanism and design of a dye-diffusion printer are similar to those of a thermal-transfer printer.

But the cost of the dye-diffusion printing, the transfer medium, and the paper are considerably higher.

A variety of dye-sublimation printers are now available, including the 300-dpi *4 Cast* from Du Pont Imaging Systems, the 200-dpi *XL 700* from Eastman Kodak, the 300-dpi *CHC-5445* from Mitsubishi International, and the 300-dpi *CH6104 Professional Color Print* from Seiko Instruments.

Towards Photographic Quality Printed Output

Colour printer technology has come a long way in the past few years, and the continuing development efforts will ensure greater progress in the future. Last year, the big news was the introduction of a number of sub-$ 10,000 PostScript-compatible thermal-transfer printers. This year has witnessed the introduction of HP's 300-dpi *DeskWriter C Ink-jet Printer* and Tektronix's 300-dpi plain paper *Phaser III PXi Printer*. The next two years will see progress toward near-photographic-quality printed output, as well as continually decreasing prices. Technological improvements will also bring high-resolutions, near-photographic-quality output below the critical $10,000 price barrier in the not-too-distant future.

The result of such advantages is that desktop colour printing is fast becoming a mainstream technology. The user is the big winner; he has the access to the power of colour to enhance his communication, both on the screen and on paper.

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