Technical Information

Color in Printing

Printing in color, whether it is a simple two-color job, or a six-color advertising piece, is a complex process involving many factors. This article will cover the basics of color printing as a foundation for future pieces.
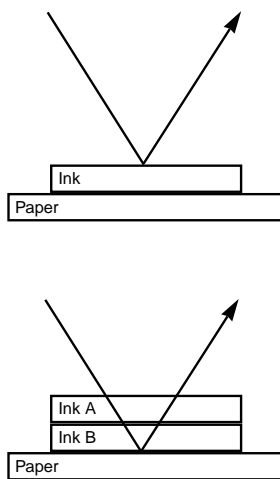
Colored Inks

Printing is the process of laying ink on paper. So, of course, the interaction between ink and paper plays a major role in the success of a printed piece. The inks used for color printing fall into two basic categories: process color and spot color. The process color inks are cyan, magenta, yellow and black, commonly abbreviated as CMYK (where K stands for black, sometimes referred to as the key, or registration color). Spot color inks may be virtually any color. The most widely used spot color system is the Pantone Matching System**, which contains over 700 colors, including metallic and iridescent colors that are extremely difficult to reproduce with process colors. Process colors and spot colors may appear on the same page, and sometimes it is even difficult to tell which is which without a magnifier.

Figure 1 - Light reflecting off of the surface of an opaque ink (top). Light filtering through two layers of transparent inks (bottom).

The way in which you use process and spot colors must be well-planned, and take into account the basic natures of these inks. Process colors are formulated to be as transparent as possible so that light passes through them and is filtered through multiple layers of ink before it hits the paper and is reflected back to the eye. However, some inks are formulated to be opaque. For opaque inks, light bounces directly off the surface of the ink and is reflected back to the eye. (See Figure 1.) This keeps the color of the paper or the underlying layers from affecting the ink color on top, but it also means that overlaid opaque inks rarely produce satisfying color mixtures. Spot colors may be formulated to be either transparent or opaque. If you plan on overlaying spot colors to produce other color mixtures, you may want to run tests to be sure that the mixtures produce the colors that you require.

Perception

Communicating the three-dimensional world into two dimensions is the goal of color reproduction. To create this kind of illusion it is necessary to understand human perception. Three things are required for perception to take place: an observer, an object and a light source. If any of these are missing, there can be no sensation of color. A variation in any of these factors will also change the perception of color. For example, the same object observed in sunlight, candlelight, moonlight, and fluorescent light will appear different under each source. Remember this when you are viewing printed material. To make valid judgements you should view material under a consistent light source. Viewing booths have been designed that simulate sunlight at noon on a clear day, and they are often used for evaluation of printed material. This is also important in the choice of a paper. The same ink may look different on various paper stocks, because of the way light reflects off of it.

Origins of Process Color

Other sources will be able to offer you a more complete (and more colorful) description of color. Still, to understand what happens in color printing, a brief overview of color theory is necessary.

**The Additive Color Primaries
and their Mixtures:**

Green + Blue = Cyan

Blue + Red = Magenta

Red + Green = Yellow

Red + Green + Blue = White

**The Subtractive Color
Primaries and their Mixtures:**

Magenta + Yellow = Red

Yellow + Cyan = Green

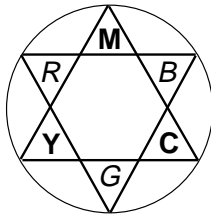Cyan + Magenta = Blue

Cyan + Magenta + Yellow ≈ Black

*Figure 3 - Color mixtures,
where C,M, and Y stand for
cyan, magenta, and yellow,
and R,G, and B stand for
red, green and blue.*

The concepts underlying process color mixtures go all the way back to Sir Isaac Newton and his experiments with sunlight and prisms. Newton found that a white beam of sunlight could be divided with a prism into the entire color spectrum. He also found that by mixing these colors back together, he could recreate the white beam of sunlight. In fact, using just three colors from the spectrum (red, green, and blue), Newton found that he could create not only white light from the mixture of all three, but he could produce many other colors with two color combinations. These two color mixtures are shown to the left. From Newton's experiments came the concepts of additive color mixing. (Additive color mixing refers to the mixing of light.)

These light mixtures may appear confusing to those who haven't seen them in practice. Red, green, and blue make white? How is that possible? The easiest way to convince yourself is to look at a color monitor with a magnifier (30x will do). White areas are actually made up of red, green, and blue sections. Yellow is made up of green and red, and so on.

The colors formed by the mixtures of the additive primaries are cyan (a light blue-green), magenta (a pinkish-red), and yellow. Further research determined that mixtures of cyan, magenta and yellow pigments produced a wide range of colors. Cyan, magenta, and yellow became known as the subtractive primaries. (Subtractive color mixing refers to the mixing of pigments.)

In conclusion, for mixing colored light the colors red, green, and blue (commonly referred to as RGB) are the primary colors. Televisions, color monitors, and desktop scanners all deal with RGB data. However for mixing pigments, cyan, magenta and yellow are the primaries. Virtually all printed materials that you see (except for some photographic processes) use CMYK. Color thermal printers, color copy machines, as well as color magazines, newspapers, and books are all examples of the use of process color.

Figure 3 provides a way to remember the color mixtures formed by the additive and subtractive primaries. Draw two triangles to make a six-pointed star, and put the additive primaries at the point of one triangle. Insert the subtractive primaries at the points of the other being sure to put cyan between blue and green, magenta between red and blue, and yellow between red and green. You can see the color mixtures formed by any two primaries (additive or subtractive), by looking at the color that falls between them. (A mnemonic for remembering the order of the colors clockwise around the circle is as follows: **M**y **B**oa **C**onstrictor **G**ot **Y**our **R**abbit.) The colors that fall opposite each other on the circle are called complements. Blue and yellow, red and cyan, and green and magenta are complements. Adding a complementary color to a colored ink makes the colored ink darker. It is as if you added black to it.

Why black?

Color theory is only a theory. In practice things work a little differently. Cyan, magenta and yellow inks mixed together don't produce black. Because of imperfections in the inks, the result is closer to a dark brown. A true black ink is needed to create deep blacks, to darken images and to add detail. As a result, black ink is needed along with cyan, magenta, and yellow to make up the process colors.

Color communication

As a child you were taught that blue, red, and yellow were the primary colors, but this simplification of the terminology can only lead to confusion. For clarity's sake, always refer to the subtractive primaries as cyan, magenta, and yellow. Printers often refer to cyan as process blue, and magenta as process red, but avoid this if you want to communicate color clearly. If someone says they want less red in any image, you need to know if they mean less red (magenta + yellow) or less process red (magenta).

Halftone dot percentages

Figure 4 - Extremely coarse half-tone; note individual halftone dots.

A printing press with black ink in it can either print solid black or not print black. Unless gray ink is in it, it cannot print a gray. To give the impression of gray you have to create the illusion of gray with black ink. This is done by printing tiny black dots (known as halftone dots) in areas where a gray is desired. Light gray areas are reproduced with small halftone dots, dark gray areas are reproduced with bigger halftone dots. The term dot percentage is used to describe how dark a gray is. White is 0% and black is100%. A 10% black, for example, is a relatively light gray. The 10% means that 10% of the area is covered with ink while 90% is left open.

Note: The relative size of a halftone dot is measured by dot percentage. The distance from the center of one halftone dot to the next is a function of screen ruling. For more information on this subject, see the technical information article entitled Resolution and Screen Ruling, part number 3050.

This terminology may be used with any color of ink. For example to describe a light green, you might say that it contains 40% cyan, 0% magenta, 70% yellow, and 0% black (or 40C, 0M, 70Y, 0K.) You know from the color chart that cyan and yellow mixed together forms green. The relative size of the percentage numbers implies that it would be a yellowish green. Lack of magenta or black implies a pure green rather than a muddied one.

Dot percentage can be measured using a densitometer. Almost all transmission densitometers can read dot percentage on film, however many reflection densitometers can only give you a density value for paper. (If you are interested in learning more about converting density measurements into dot percentage values, contact the author at the address on the back page.)

Process color

Process color is the most commonly used system for reproducing multi-color images. It is relatively inexpensive, and is able to reproduce a wide range of color through the use of only four colors of ink. It does this by printing different amounts of the colors on top of each other. Because the inks are virtually transparent, light that passes through them is filtered, so that when it reflects to your eye one of a broad spectrum of colors is perceived. As a result, process color inks are used to simulate the spectrum of colors that occurs in color photographs and artwork. And although we usually refer to process color as four-color printing, occasionally additional spot colors and varnishes may make a job 6, 7, or 8 colors.

Spot color

Spot color is used when a particular color match must be obtained, for example in the case of a company logo on a business card. A specially mixed ink is used to obtain this match. A common source of confusion occurs when a user of a desktop publishing program chooses a spot color (most probably from Pantone) and then selects process color separation. The color they get may not be the color they want. The Pantone color will be converted into percentages of cyan, magenta, yellow, and black, and there is no longer a guaranteed color match.

Color separation

Until recently, color separation was solely the realm of the color trade shop. Today, many desktop publishing programs are able to do some level of color separation. In the course of this evolution, the term color separation has taken a beating. Previously, color separation was taken to mean turning photographs and artwork into four films (representing CMYK) that could then be used to make a printing plate. Now, the term has been broadened to include operations that are color separation in only the very loosest sense.

At its simplest, color separation involves handling the separate elements of a printed piece so that they can be printed in two or more colors (often with a spot color ink.) An example is a business card where the company logo appears in color and the employee's name is in black. You could either print out the separate pieces of film, or output one piece of film and instruct the

printer to cut out the type that will print in another color and mount it on a different piece of film. This is commonly know as stripping, not color separation.

It is important to know the level of color separation that a program can handle. Does it do electronic stripping of type, tints and rules? Does it do electronic stripping of synthetic images (those from Adobe Illustrator** or Aldus Freehand**)? Does it handle the separation of scanned images?

Ink use

The ability of ink to adhere to paper is called ink trapping (not to be confused with trapping, the slight overlaps between adjacent colors that adjust for imperfect printing press registration). Ink trapping occurs on paper that already has at least one layer of ink on it. Poor ink trapping results in printing press problems when either the ink won't stick to the paper, or it sticks so well that the paper adheres to the plate and tears.
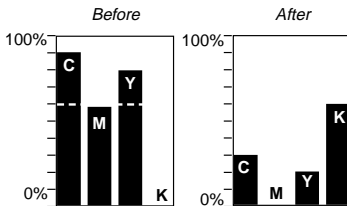
Figure 5 - UCR. According to subtractive color mixing theory, equal portions of C, M, and Y should make black. Therefore, these CMY portions of a dark color may be removed and replaced with black ink. In this example, the total ink coverage is reduced from 230% (90C, 60M, 80Y, 0K) to 110% (30C, 0M, 20Y, 60K). This diagram represents 100% UCR, more commonly a smaller percent of UCR, perhaps 50% is used.

In color printing today, multiple layers of ink are laid down before the lower layers are given any chance to dry. (Paper in high-speed printing presses moves along at up to 30 miles per hour.) This kind of printing, called wet-on-wet, requires that wet ink stick to paper that already has ink on it. Inks have been developed that allow this, but their job can be made easier if UCR (Under Color Removal) and GCR (Gray Component Replacement) are used. UCR and GCR are techniques that reduce the amount of colored ink that is printed on a page. They do this by replacing three color gray shades with black (in the case of UCR) or by replacing the gray components of certain colors with black (GCR). By replacing cyan, magenta, and yellow ink with black, the total amount of ink may be reduced without degrading the image.

The important point to keep in mind is that in creating colors in a desktop publishing program, special attention should be paid to keeping the total ink coverage as low as feasible. 400% is the maximum amount of ink that you could possibly put on a page (100%C, 100%M, 100%Y, and 100%K). Most printers prefer totals in the range of 250% to 320%. For example, don't create a color made up of 90% cyan, 90% magenta, 90% yellow and 90% black. That would create a total of 360% coverage, which most printers would find very difficult to manage.

A final note

When you supply films that are plate-ready (i.e., nothing needs to be done before the plate-making process), most often the printer wants emulsion-down, right-reading, negative films[1]; if the printer needs to do additional work on the job, they may prefer positives, either on paper or film. (For more information, refer to the Linotype-Hell technical information piece entitled Analyzing Film Output, part number 3062.)

[1]The description "emulsion-down, right-reading, negative films" means that the films are negative and the type is readable (not mirrored) when the films are laid emulsion side down on a light table. The emulsion side looks duller than the base side. If you have trouble telling which side is the emulsion side, take a sharp object and try to scrape off some of the black from a scrap piece of film. You will be able to do this on the emulsion side, but you will only scratch the base on the base side.

Comments

Please direct any questions or comments to:

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