High Fidelity Seven Ink Printing

Seven ink printing is a cornerstone of high fidelity color. What is high fidelity color? In general, the term ‘high fidelity’ (or ‘hifi’) color describes a variety of techniques used to make printed pieces look better, including:

- More than four color, often printing with seven inks (six colors and black)
- Gray component replacement (GCR) techniques designed for more than four color separations
- Frequency modulated (or stochastic) screening methods
- Premium papers
- Special techniques like die cuts, varnishes, laminates, specialty inks (like fluorescents), touch plates, etc.

In this article we will look at the issues surrounding seven ink printing. Some background information on other aspects of high fidelity color may be found in these articles from the 1993 Linotype-Hell Technical Information notebook: *Diamond Screening, Color Gamut, Technology Update: Diamond Screening, and Beyond Color.*

Seven ink printing

Why would anyone want to print seven inks?

- Seven inks can print a larger color gamut which includes colors that the four process color inks cannot achieve.
- Seven inks can achieve a brighter color appearance and improved modulation of color.
- Seven inks allow closer color matches to the original.
- Printing with seven inks produces cleaner reds, greens, and blues.

Simply put, seven ink printing expands the color gamut of the printed process. The four most commonly used color inks, cyan, magenta, yellow, and black (CMYK), are able to reproduce a remarkable range of colors, but they are limited in certain areas, most notably the reproduction of blue and green. In fact, all of the secondary colors, red, green, and blue, must be mixed from combinations of cyan, magenta, and yellow. The result is reds, greens, and blues that are not as clean and saturated as they would be if they had been printed as a single ink.

Of course a limited color gamut has always been a problem for color printers. And while it is possible to assign a separate ink color to each hue in an image (much as the 19th century American printmakers Currier and Ives did), such a scheme is not economically feasible for the reproduction of photographs. The solution is to find a limited number of inks that produce good results. CMYK inks have done this, but that does not eliminate the possibility that other ink sets might also perform well.

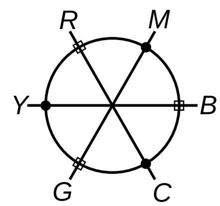
Seven ink printing poses a number of interesting technological challenges to the prepress and printing industries which will be covered in this article. The box on the following page provides some background on color terminology used in the article.

Complementary color pairs…gray components…primary, secondary, and tertiary colors

The illustration below shows colors evenly distributed around a color wheel. Lines connect pairs of colors. These are called complementary color pairs. For the purpose of understanding GCR (gray component replacement), a hue's complement is also its gray component. (See below.)

In considering CMYK printing, the primary colors are cyan, magenta, and yellow. Secondary colors are made up of mixtures of two primaries. Tertiary are mixtures of three primaries. (See below.)

Hue	***Complementary Color or Gray Component***
Red	Cyan
Green	Magenta
Blue	Yellow
Cyan	Red
Magenta	Green
Yellow	Blue



Primaries *(subtractive primaries)*
Cyan, Magenta, and Yellow

Secondaries *(additive primaries)*
Red, Green, and Blue

Tertiaries
Browns, grays, darkened colors like dirty reds, greens or blues (i.e. colors with a complementary color component), and all intermediate colors.

GCR, UCR, and UCA

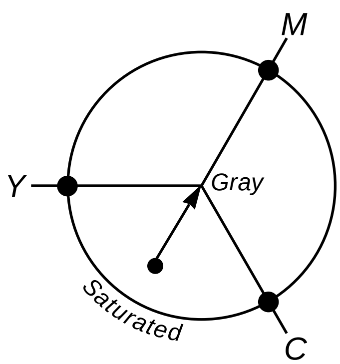


Figure 1 – Simplified illustration of a color wheel where the black dot inside the circle represents a green hue formed by mixing yellow and cyan. The center point of the circle represents neutral gray. Since magenta is the gray component of green, adding magenta will only make the green darker or more gray.

Theoretically, cyan, magenta, and yellow inks should be able to reproduce a color image. In practice, they just don't produce a convincing solid black. The result is that images reproduced with just cyan, magenta, and yellow lack picture contrast.

A number of different methods have been developed to create a satisfactory black plate. GCR, UCR, and UCA all play an important role in this:

- **GCR** – Gray component replacement is a color separation technique that removes some or all of the cyan, magenta, or yellow for a given color ink, and replaces it with black.[1] The key term in gray component replacement is the word gray. For example, in four color printing a green hue is made green by combining cyan and yellow ink. Adding magenta ink to this green mixture will not make it any greener, in fact, it will only make it darker and more gray. (See Figure 1.) Therefore in the example of a green hue, magenta is the gray component. GCR replaces the gray component (in this example, magenta) with black. 100% GCR completely replaces the gray component with black. If 100% GCR were used then only two colors plus black would occur in any local part of the image. Lesser percentages of GCR are more commonly used and recommended.
- **UCR** – Under color removal, like GCR, reduces the cyan, magenta, and yellow portion of a given color, but UCR, rather than being used throughout the entire image, is only used in the neutral areas. For example, a dark neutral area might contain 70% cyan, 60% magenta, and 60% yellow.[2] UCR reduces those values and replaces them with black. For example, 100% UCR would change 70C, 60M, 60Y to 0C, 0M, 0Y, 80K. Total ink coverage in that area of the sheet would thereby be reduced from 210% to 80%. As with GCR, generally less than 100% UCR is used, often 20-60%.
- **UCA** – Under color addition adds color into dark neutral areas. The reason for this is that a dark neutral composed of multiple inks will have a richer appearance than the comparable tint of black only. (This translates to a higher reflection density as measured by a densitometer.) By adding some color beneath the black tint, some of the density and richer appearance may be maintained. UCA is used in combination with GCR or UCR.

Prior to GCR, UCR, and UCA, the black plate was often called **skeleton black** because it was most noticeable in the darkest areas of an image. A skeleton black plate adds contrast and detail. One drawback with a skeleton

[1] In the case of seven ink printing, the colors removed may also include red, green, or blue.

[2] While it seems logical that a neutral gray would be comprised of equal percentages of cyan, magenta, and yellow, in practice this is not the case. A neutral gray usually contains more cyan than magenta and yellow. The exact percentages depend on the inks themselves and the paper they are printed on.

black plate is that in the darkest areas of the image there may be 100% of each color ink printing all in the same area. This amount of ink (what we will call 400%, because it amounts to 100% cyan, 100% magenta, 100% yellow, and 100% black ink) can cause ink trapping problems for the printer.[3] **UCR** is the immediate solution to this because it only affects the dark neutrals and brings down the ink totals in those dark areas (without making the blacks look too weak).

[3] Ink trapping refers to the ability of an ink to stick to paper that already has ink on it. Printing many colors on top of each other increases the likelihood of ink trapping problems.

Today the term trapping is also used in another sense to refer to the slight overlapping of adjacent colors. This overlap prevents the white of the paper from showing through as registration changes.

The next step is **GCR**. GCR affects the entire image. With 100% GCR, no color in an image will be produced with more than two colors and black (of course that means no more than 300% total ink coverage). This type of reproduction is also called **achromatic reproduction**, because black ink is used to darken rather than color ink. GCR reproductions tend to be more stable on press. (They are less sensitive to color shifts due to registration variations during the press run.) They also have better shadow detail, and because of the smaller amounts of ink being printed in any given area they tend to have less problems with ink trapping. However, one drawback of using large amounts of GCR is that it can cause unwanted artifacts, particularly in areas of subtle tone changes. GCR is particularly popular in web printing environments because of the advantages for ink trapping (so-called wet-in-wet printing).

UCA affects only the darkest areas of an image, you might well choose to have a high level of GCR or UCR, and yet use UCA to assure that dark grays and blacks appear dense.

Color separation and GCR techniques are particularly important in high fidelity color printing because of the additional inks. Imagine trying to print a neutral gray with 6 colors! With proper application of GCR, there may be only black and two colorants in any portion of the image. GCR techniques are not trivial. When applying strong GCR[4], some GCR algorithms simply fail. Browns may lose chroma or become dirty, and artifacts may be generated.

[4] Strong GCR generally means that the remaining gray component is limited to under 10% dot area.

DC 3000 color separation

With Linotype-Hell DC 3000 software, predefined GCR tables are offered through programmed color reduction (PCR). With NewColor 3000 there is a GCR control with automatic print dependent UCR and black calculation. Additional colors, touch plates for example, may be created by individual adjustments in the current implementation of the software. Later, in the summer of 1994, predefined 5 to 7 color separations sets will be available as an option. Programmed color transformation (PCT) will be used to achieve these 5 to 7 color sets. A seven ink color separation will require two passes by the scanner. The first scan captures CMYK while the second scan captures RGB.

Screening and angles

Depending on how the color separation is handled, seven ink color separations may be screened with either frequency modulated or conventional screens. If conventional screens are used, the separations require a high amount of GCR to avoid moiré.

In general, conventional screen angles and rulings are not well-suited for printing more than four colors. This is due to the problem of trying to separate each color by at least 30° (or in the case of elliptical dot shapes, 60°). (More information on screen angle, screen ruling, and moiré may be found in the Color section of the 1992 Linotype-Hell Technical Information notebook.) With frequency modulated screens the issue of screen angle and ruling is no longer an issue.

This is not to say that it is impossible to do seven ink printing with conventional screens. It is possible, but care has to be taken with the way that the color separation is produced. Consider this: in a CMYK separation,

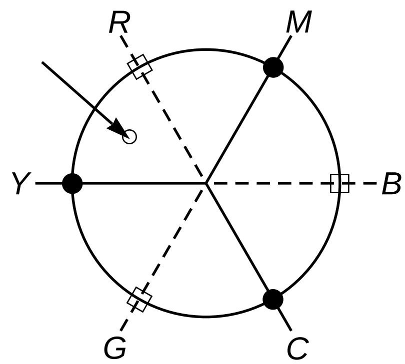


Figure 2 – In a seven ink printing scheme, orange could be reproduced using just red and yellow inks. Black could be added to darken it.

certain tints may be made up of varying percentages of all four colors. With all four colors in such close proximity, the angles must be carefully handled to avoid moiré. When using six colors plus black, it is easier to isolate colors such that in a given area only two colors are used along with black. Consider the color wheel shown in Figure 2. A particular shade of orange might fall where the circle is on the color wheel. That orange color could be reproduced using tints of the neighboring red and yellow inks. To darken it, black could be added. If the image were separated using this kind of model, it would only be necessary to assign different screen angles to the primary colors (CMY), the secondary colors (RGB), and black (K) like this:

- Yellow, magenta, and cyan at 15°
- Red, green, and blue at 75°
- Black at 45°

In this manner, complementary colors (red/cyan, green/magenta, and blue/yellow) are offset by 60°. Yellow, magenta, and cyan may all be the same screen ruling, because in a seven ink scheme with the proper GCR settings they will never overlap (or only overlap in very small amounts). The same holds true for red, green, and blue.

Seven ink sets

There is no single standard for seven ink sets. (Remember that even with CMYK inks, not everyone's CMYK is identical). Researchers are working on these questions:

- If you use more than four colors, which ones do you use?
- Do you continue to use the existing CMYK or choose entirely new colors?
- How will you proof these colors?

Some of the multi- color ink sets either proposed or in use today are:

- K&E (BASF) with Inno Eder – 7-color ink set which has been available since 1990
- H. Küppers 7-ink color process (supplied by Gebr. Schmidt Company)
- A yet to be published FOGRA model

Conclusion

It is clear from the preceding discussion that a number of technologies have come together to support high fidelity color. The success of high fidelity color will depend not only on the technologies themselves, but also on how they are used in conjunction with many other technologies.

Acknowledgements

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