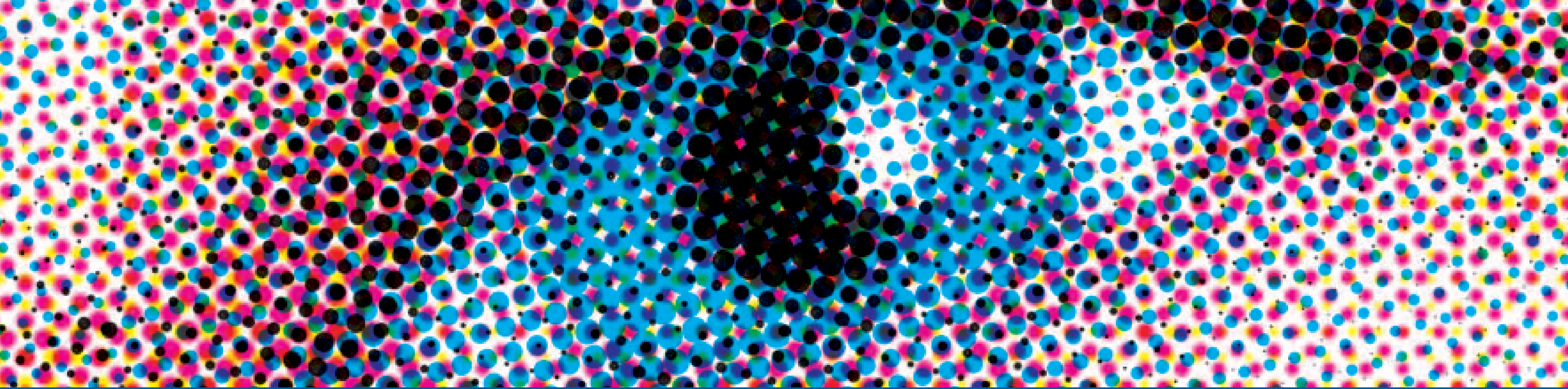


An Introduction to Screening Technology

HEIDELBERG

Contents

Prologue

This book was written to help the user become familiar with digital screening. It provides an overview of the various screening technologies with the emphasis on the high-performance technologies of Heidelberger Druckmaschinen AG (Heidelberg®). It explains not only screen setups in the PostScript[1] and PDF[2] page description languages but also setups via the JDF[3] workflow format. It also provides some tips and tricks for dealing with these systems.
Over the years, a wide array of digital screens were developed, offering special benefits for specific uses. Excellent reproduction results are possible if users have the know-how for choosing the best screen. That is where this book will help. Unfortunately, there is no universal screening system for all applications. Attention will be drawn here in particular to the new developments Prinect® Stochastic Screening and Prinect Hybrid Screening.
Prinect Stochastic Screening from Heidelberg is a frequency-modulated screening process. It is a successor to the 2nd generation of FM screens, offering a previously unattainable resolution for offset printing bordering on photographic realism. It also produces print results of a smoothness never before achieved with FM screens. Detailed information can be found in the chapter dealing with FM screening.
Prinect Hybrid Screening is a combination of conventional screening and FM screening that harnesses the benefits of both. For the light tonal values ('highlights'), small dots with a defined minimum size are positioned in a quasi random way. Similarly, for the dark tonal values ('shadows'), small holes with a defined minimum size are left open. This enables these tonal ranges to be printed stably without appearing coarsely screened. Conventional screens are then used for the mid-tones as these have a particularly smooth effect, especially at high screen frequencies. With Prinect Hybrid Screening, a high screen frequency results in very good detail definition. The print results are also excellent and the print performance highly stable, making it an ideal screening process in many respects.
In order to select the correct screen for a specific purpose, the user must be aware of the many factors that can influence screening. Thus, the first few chapters of this book contain a few fundamental explanations about the screens, specific screening aspects, screen-related aspects in printing, and RIP (raster image processor)[4] and imagesetter properties.
Customers, agents, trade schools, universities, colleges and other interested parties have asked Heidelberg for information about screening and the technologies involved. Since this book is aimed at a broad spectrum of readers, little prior knowledge about screening is needed. However, to understand the general context, basic knowledge about printing and color reproduction is helpful. The use of mathematical formulas has been kept to a minimum, and they have only been used to illustrate a point, whenever this was necessary.
The print examples in this book are on separate sheets to facilitate comparison, so the reader can place any two print examples next to each other in order to compare them directly.
Since this book can also be used as an electronic medium, enlarged bitmaps of the screens are included in addition to the print examples used in the two previous editions. Viewed on a monitor, these should give an impression of the overprinting properties.
This book is not intended to replace formal training, but it will probably offer even the experienced operator some interesting tips.
And so, without further ado, we hope you enjoy it.

1 General Screening Information

1.1 History

Ever since man has had the wish to reproduce and print images, artists have been asking themselves how they can solve the problem which contones and the tones in between present.
Woodcut, the earliest form of letterpress, was accomplished by using knives to carve lines for ornaments and simple figures. Before Gutenberg invented poured and movable type in 1450, complete printing forms with text and images were made of woodcuts. The woodcuts were limited to clearly defined contours, and rarely did the depicted objects contain any detail. Instead, the prints were hand-painted afterwards in order to give the illusion of plasticity.
Slowly, artists during the Middle Ages were able to create lifelike representations graphically by inventing crosshatching. In order to differentiate light from shadow, as well as contones, the artists carved horizontal, vertical, diagonal or curved lines over and next to each other. By crossing over lines several times, as well as by adding hooks and dots, they elaborated continually on the system of crosshatching. This technique was perfected in copperplate engraving, which eventually evolved into the versatile reproduction process of gravure printing.
Etching, the process where a drawing is engraved onto a metal plate, was just one of the many other artistic techniques to follow. The lines in crosshatching can be closer in an etching than in a copperplate engraving and thus produce the effect of a chalky gray.
Wood engravings achieved extremely fine nuances of light and tonal gradations by covering the surface with dots. Intersecting white lines resulted in the soft, almost picturesque transition between light and dark that is so typical of wood engravings.
Lithography, which was invented in 1798, used sandstone's natural grain to simulate intermediate tones. Greased sticks were used to draw a print copy on stone. Grease particles, the size of which depended on the contact pressure, adhered to the grains. In this planographic printing process, the grease particles absorbed the oily ink, while the damp stone repelled it. That is how prints were transposed from drawings to stone. This process made it possible for the first time to simulate contones using minute elements so that they were no longer viewed as a disturbance.
All of these processes had one common goal: To create the perfect illusion of reality; a goal that was nevertheless instantaneously derided as being 'unrealistic' when photography was discovered in the middle of the 19th Century and became an immediate success.
Since then, photography has been able to recreate people, animals, nature, objects and everyday scenes as the eye perceives them to be. Film which was invented in 1887 has also made it possible for us to make any number of copies of the original in any size desired. It is only when photographs are used in print that compromises must again be made. And this is when we think back fondly on the techniques of the old masters.

1.2 What is a Screen?

Unlike photography, differences in lightness cannot be directly reproduced in offset printing. Printed paper either has color or none at all at any given location, meaning there is no such thing as 'a little color'. However, screens trick the human eye into thinking that it sees differences in lightness.

In a black-and-white image, different gray tones can be simulated by printing a number of small dots larger or smaller. These small dots are arranged at regular intervals in a grid structure that is called a screen or halftone screen.
The classic screen with a regular, usually square grid structure, has a screen period and a screen angle. The reciprocal of the screen period is called screen frequency, screen count or screen ruling and is measured in lines per inch (lpi) or lines per centimeter (l/cm). To keep things simple, the dot shape in Figure 1 is shown as a circle, although dots can come in elliptical,

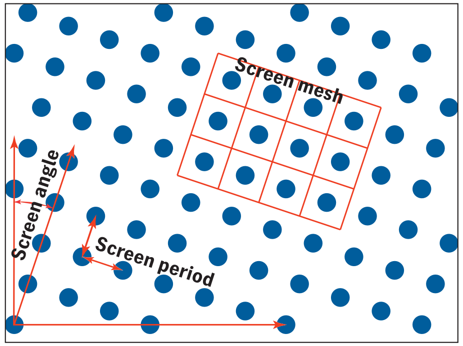


Figure 1: Example of a screen.

square, round-square, rhombic or other shapes, and the shapes within light, mid-tone and dark areas may vary yet again.
The screen described here is called an amplitude-modulated screen because the number of screen dots is fixed and only their size is varied. There are screens with regular structures and screens with irregular structures, as you will read later on in the chapter covering frequency-modulated (FM) screening. Parameters that can be applied to regular screens such as screen frequency can't be used in this case, so the smallest dot size is often used as a criterion instead.
Usually, screening is used as a helpful tool for producing print media, but in some rare cases it is also used as an artistic design element. Accordingly, the screen should not be visible to the observer or if so at least not in a disturbing way.
The principle used in black-and-white printing can be applied to color printing as well. All color artwork is digitally broken down into a series of printing colors. This is called 'color separation'. By far the most common process is separation into the colors cyan, magenta and yellow. Black is added as the fourth color to reinforce contrast. These colors are also known as process colors. Every color image can be broken down into process color separations with the help of suitable filters and can be printed with the help of screening. Screening is the art of fooling the human eye into believing it sees a natural-looking color image using just the process colors printed as a solid tint. As with all forms of art, screening requires substantial expertise.
Before we delve into screening processes any further, we will first look at two fundamental effects that can occur when screens are printed on top of each other – moiré and color shift.

1.3 Moiré

If two screens with slightly different screen frequencies are superposed, disturbances occur in the pattern. These superposing effects are called moiré. This also occurs when the two screens are rotated by slightly different angles. Both effects are shown in figure 2.

1.4 Color Shift

An extreme case of color shift occurs when two identical screens with different colors are printed on top of each other. During the printing process, a slight shifting of the color separations cannot be excluded, which means that screen dots are sometimes printed on top of each other and sometimes side by side. The resulting color will be very different each time, as illustrated in Figure 3.
Similar but less significant effects can also occur under particular conditions when different screens are superposed. Color shift is actually nothing more than very long period moiré. However, the eye perceives the effect as color shift.
Screens that tend to color shift in printing are avoided because you cannot control the results. The extreme example shown here of two screens with the same angle and frequency cannot occur using a Heidelberg screen system.

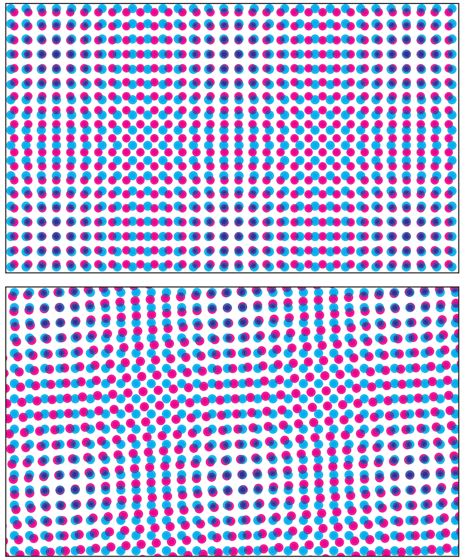


Figure 2: Example of moiré resulting from differing screen frequencies (top) and from screen rotation (bottom).

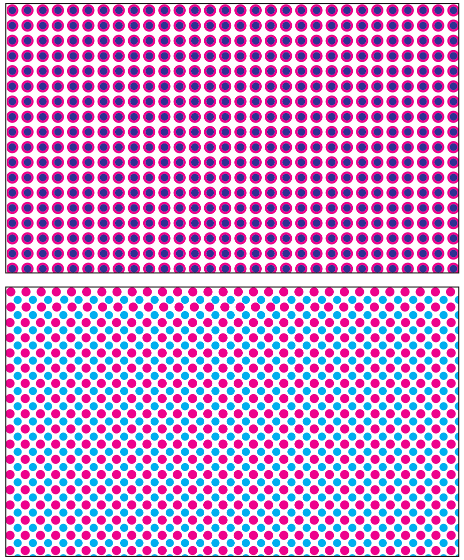


Figure 3: Example of color shift: The same screens printed on top of each other and side by side.

1.5 Imagesetter Pixels and Screen Dots

Today, plates and films are produced almost without exception using laser imagesetters. All laser imagesetters work on the same principle, whereby a laser beam, or several in parallel, moves line by line over the film or plate. The laser is switched on in those areas where the film or plate is to be exposed; and where no exposure is required, the laser is switched off. The laser beam is switched on and off digitally at precisely defined cycles, as illustrated in Figure 4. The smallest laser dots are known as pixels, a somewhat ambiguous term deriving from 'picture element', and each screen dot is made up of a certain number of pixels. This principle lies behind the way a screen is constructed into the pixel matrix of an imagesetter. Understanding this is important in order to understand the upcoming chapter on screening methods and technologies. As described here, an imagesetter is controlled by a bitmap made of pixels.

Two different systems of measurements are normally used for imagesetter resolution and screen frequency. In one version, the imagesetter resolution is given in dpi (dots per inch) and the screen frequency in lpi (lines per inch). In the other version, metric units are used. With this system, both the imagesetter resolution and the screen frequency are measured in lines per centimeter (l/cm)[Footnote5].

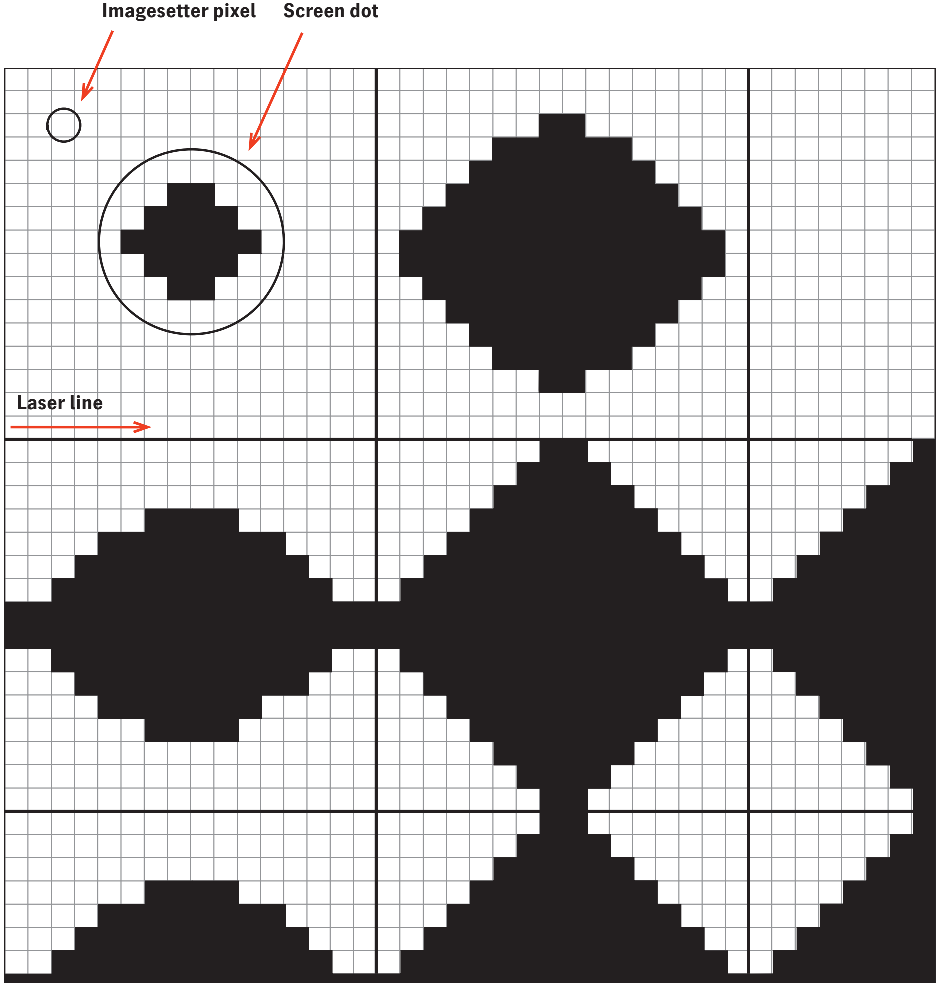


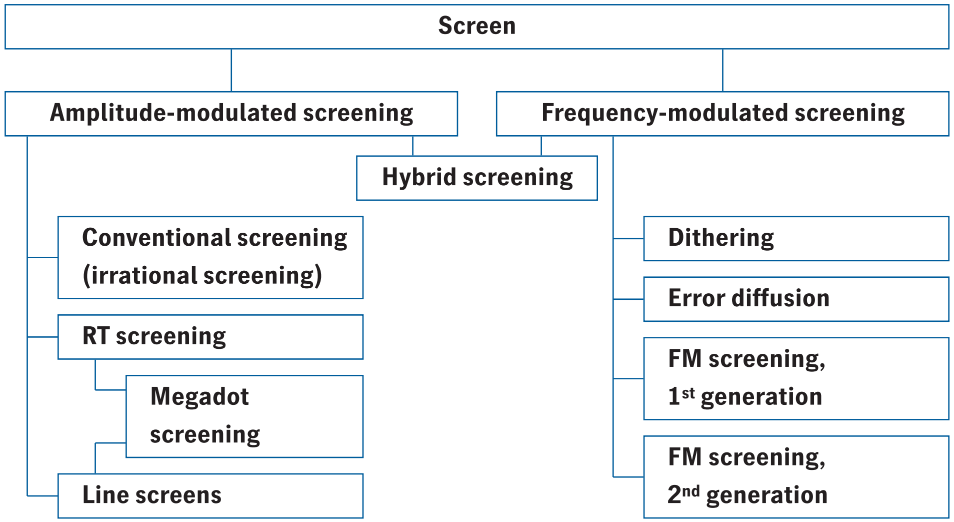
Figure 4: Imagesetter pixels and screen dots.

2 Screening Methods

Traditional screening methods were described in Chapter 1.1. In this chapter, we will cover digital screening, but we will also include old screening methods when we discuss conventional screening. The main purpose of this chapter is to talk about screening characteristics that are not linked to implementation matters.
The screening family tree below provides an overview of the screening methods examined here. The screens and their interrelations are then described in the text.

2.1 Amplitude-modulated Screening (AM Screening)

Amplitude-modulated screens are made up of compact screen dots arranged equidistantly. As the tonal value increases, the individual screen dots become larger, i. e. their 'amplitude' becomes larger, while the screen period and therefore the frequency remains constant. They are therefore known as amplitude-modulated or AM screens. The conventional screens defined below are a classic example of amplitude-modulated screens.



2.1.1 Conventional Screening

We know that, to be used in print, photographs must first be converted to screened artwork, but the question is 'how?'. The most common solution in the early days of this technology was to use the repro camera. A precision-made rotatable glass plate was placed in front of the film that was to be exposed. The glass plate was etched with a screen pattern and when the individual color separations were exposed, the image and the screen were superposed on the film, resulting in a screened image. Of course, color filters were still required to create the individual color separations.
Conventional screening evolved through trial and error. In soon became clear what difficulties were involved in overprinting colors, especially where moiré was concerned (see Chapter 1.3, Moiré). Without knowing the mathematical correlations, it was discovered that cyan (C), magenta (M), yellow (Y) and black (K = key[6]) had to be positioned at the 15°, 75°, 0° and 45° screen angles in order to achieve the best results in the overprint. Because of the way separations were produced, they all had the same screen frequency. Conventional screening is the answer to solving color shift and moiré.
Conventional screening systems is the term used to define screening systems that have the same screen frequency in all color separations. Only the frequency of yellow may vary a little. Cyan, magenta and black are typically positioned at 30° intervals from each other, and these intervals must be observed to within very narrow tolerances.

2.1.1.1 Screen Angles

When elliptical dot shapes appeared, the intervals between the angles for the defining colors cyan (C), magenta (M) and black (K) were increased from 30° to 60°. Yellow (Y) as the lightest or least defining of the four process colors is sandwiched in between so that it only 15° away from its neighbors. In conventional screening, the smaller distance between yellow and its neighboring colors can cause the overprint to have

a slight yellow moiré in skin tones in particular or in smooth gray-green tones. This latent yellow moiré is tolerated.
It is not normally visible in the overprint. It is visible, however, when the color separation films are placed on top of each other. The usual color/angle arrangement is as follows:

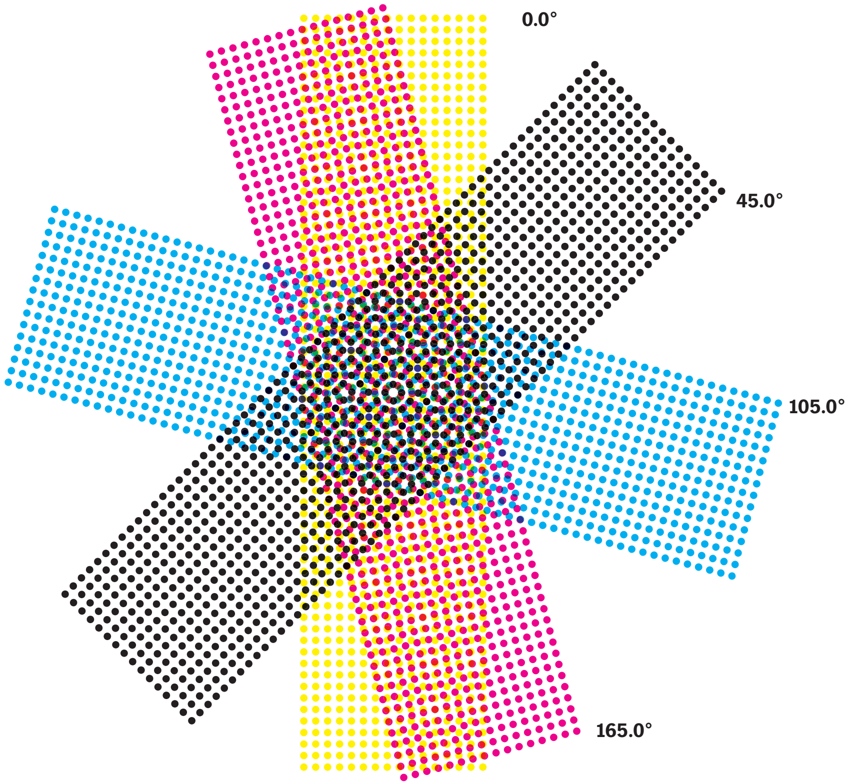


Figure 5: Cyan, magenta and black are spaced 60° apart to avoid moiré.

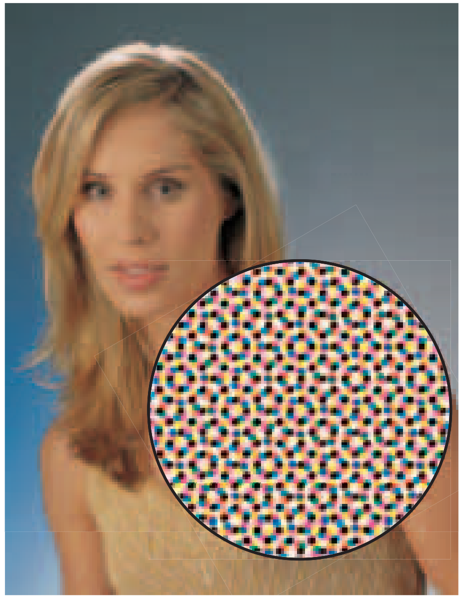
2.1.1.2 Overprint Properties in Conventional Screening

Conventional screening produces offset rosettes in the overprint (see Figure 6). This rosette is also an overprint moiré. According to studies by FOGRA[7], the rosette actually appears coarser to the observer than the screens for the individual separations. The rosette seems like a screen with one and a half times the screen period and is clearly recognizable up to a 60 l/cm screen. Only from an 80 l/cm screen upwards is it no longer visible to the naked eye.
In itself, rosette formation is an unwanted occurrence. However, its presence is so closely associated with printing that it tends to be misinterpreted as a quality criterion. In digital printing, attempts are sometimes made to imitate rosette formation so that the result has a 'printed' appearance.
Some brochures include absurd discussions about rosette shapes and which ones are better. When screen dots are arranged around a white area, this is known as a 'clear centered' rosette (see Figure 6). With digital screens, this rosette form appears of its own accord. In practice, however, exact 'clear centered' rosettes are seldom seen as every misregistration[8], no matter how small, influences the shape. In extreme cases, this can also result in a figure with a dot in the center known as a 'dot centered' rosette. In the shadows[9], the 'clear centered' rosette is slightly more open.

Table 1: Color/angle arrangement

Color/angle arrangement	
Color	Angle
Cyan	105.0°
Magenta	165.0°
Yellow	0.0°
Black	45.0°

Figure 6: This is what an offset rosette looks like when viewing a conventional screen through a magnifying glass.



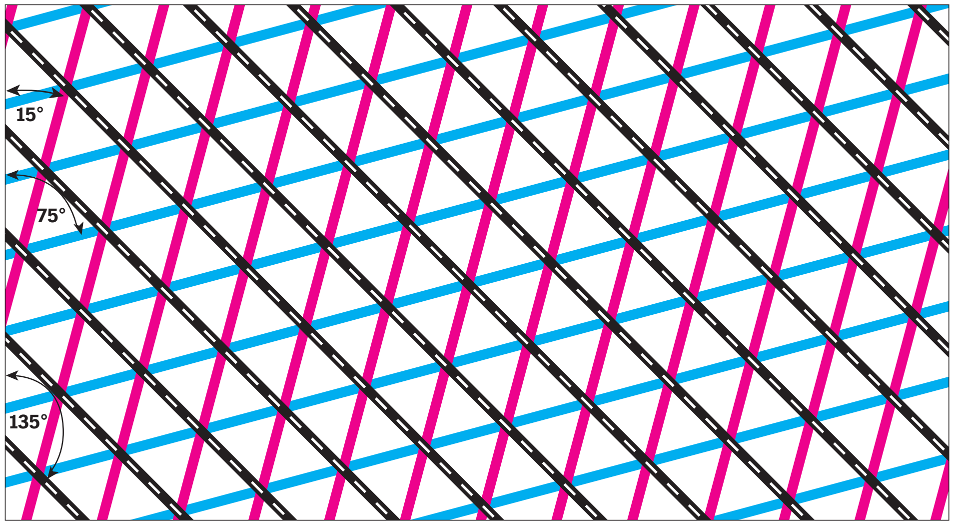
2.1.1.3 Accuracy Requirements

In conventional screening, the colors cyan, magenta and black are spaced 60° apart at the same screen frequency. Every pair of colors forms a moiré with exactly the same screen frequency and angle as the third color.
Conventional screens are characterized by the fact that the moiré period can be infinitely large in the overprint.
An example of this phenomenon is shown in Figure 7. For the sake of clarity, line screens have been used instead of the usual dot screens. Cyan and magenta form a moiré at 45° with an identical screen period (equilateral triangles). This usually isn't visible since the period is too fine. Problems occur when the black separation, which nominally also has the same screen frequency, is superposed at 45°. Many hues will have a long-wave moiré or color shift if even the slightest deviations in screen angles or screen frequency occur in the screen. This is a 2^{nd} order moiré, as here a color interferes with the moiré of two other colors. If unwanted effects such as color shifts or moirés are to be avoided in overprints, you must keep to very stringent tolerances in your work. A color shift has the most impact if distortion amounts to one color period across the format. If you are unlucky, in some cases a color shift can still have a maximum effect with half a period. This means that, if you want high-quality work, a deviation of 1/4 of a screen period across the entire format can just about be accepted.
On an A2-sized sheet that has a screen of 150 lpi (60 l/cm), the tolerance can be easily estimated:

- The diagonal is approx. 723 mm.
- 1/4 of the screen period is approx. 42 µ.

The maximum deviation for the screen angle is 0.0033° and the maximum deviation for the screen frequency is 0.0035 l/cm. These accuracy requirements are applicable for the entire production process, but it is not always possible to comply with them in printing. Therefore, it is all the more important to be as accurate as possible when generating screens so that errors don't become cumulative.
In practice it is not quite so critical, as in most cases several pages of smaller formats are arranged on one sheet. Furthermore, this color shift is only clearly visible with particular color combinations. Particularly critical are large areas of gray tones built up chromatically.
Although the tolerances specified in the old DIN 16547 regulations were broader, they were based not on what was required but on what was technically feasible at the time.

Figure 7: Cyan and magenta produce a moiré at 45° (shown as a broken line) that with black leads to a moiré. In the interests of clarity, a line screen was chosen with angles different from those in the description.



2.1.2 Rational and Irrational Screening

Rational screens, the first digital screens, were developed at a time when computer performance and memory was still very expensive. Rational screening attempts to reproduce conventional screens as accurately or intelligently as possible.

To explain how this works, we will need turn our attention to mathematics. We will therefore use the standard means of counting angles used in mathematics (counter-clockwise, 0° horizontal).

The pixel matrix of an imagesetter is a digital representation of the mathematical coordinate system. Screens have to be constructed into this pixel matrix.

The simplest way to create a rotated screen dot is to line up a certain number of (a) pixels in one direction and a certain number of (b) pixels perpendicular to these. This produces a screen, the angle of which can be described using the function arctan(b/a)[Footnote 10].

The term 'rational' refers to the number b/a. However, to start with, let us look briefly at these somewhat strange terms, 'rational' and 'irrational'.

These terms are taken from mathematics. They define sets of numbers with certain characteristics. A rational number is one that can be constructed as a fraction of integers.

Examples:

0.333333333...	= 1/3
0.25	= 1/4
tan (45°)	= 1
tan (18.4...°)	= 1/3

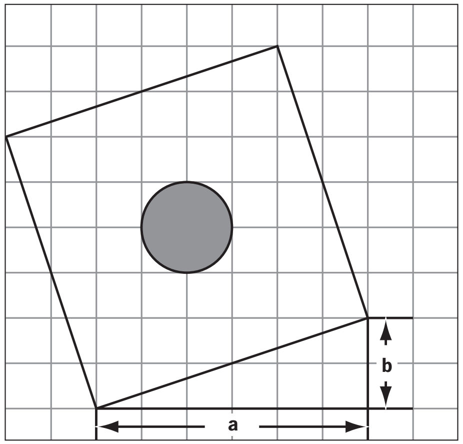


Figure 8: Example of a rational screen angle.

The opposite is an irrational number. These numbers cannot be constructed as fractions of integers.

Examples:

√2	= 1.414213562373095048...
tan (15°)	= 0.267949192431122706...
tan (75°)	= 3.732050807568877293...

That's about as much as we need to know about the theory of numbers. But remember, irrational numbers are well named.

Whether a screen is rational or irrational depends on the screen angle's tangent. Typical rational angles are 0°, 45° and 18.4° with tangent values of 0, 1 and 1/3. Typical angles with irrational tangents are 15° and 75°. In other words, the conventional screen is irrational.

Based on this definition, we actually ought to talk about screen angles with rational tangents and screen angles with irrational tangents, but since this is too complicated for daily use, we talk about rational and irrational screening.

In multicolor printing, the term 'rational screening systems' is used when all color separations in a screening system have rational screen angles. If one or more color separations have irrational screen angles, the term 'irrational screening systems' is used.

Irrational screens are highly complex to calculate. Rational screens on the other hand can be constructed into the pixel matrix of the imagesetter and are therefore much faster to process. This dilemma has been a bugbear for digital screening for many years.

With increasing computer power and optimizations, rational screening processes gradually came close to conventional, irrational screening. Thanks to the development of specialized hardware and the further development of algorithms, irrational screening finally became possible in the digital world too.

2.1.3 RT Screening

The attempt to recreate the angles of conventional screens digitally was the starting point for the development of RT screening. Its evolution was shaped by the need to make do with a minimum of memory, which at that time was very expensive. This resulted in a screening technology in its own right that has its own special advantages over conventional screening. RT screening was the first rational screening method and the first ever digital screening process. The term 'RT' stands for 'rational tangent'.

Unlike conventional screens, the aim is not to angle the possible moiré periods in the overprint towards infinity, but rather to achieve such a small moiré period that any overprint moirés become invisible.

For simplification, the RT screens are described here using only examples with 0° and 45° angles. Screen frequencies are chosen so that the size of three screen dots set at 0° is the same size as two diagonals of the dots set at a 45° angle. This produces two screen tiles of the same size with such a small repeat period in the overprint that no moiré is visible.

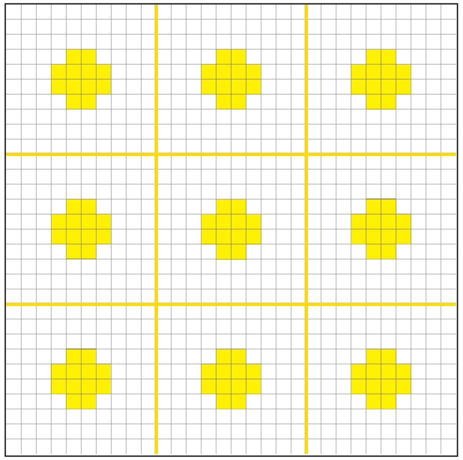


Figure 9: 0° screen dots. Dots set at a 0° angle can easily be created and a larger area is screened by simply lining up the screen dots.

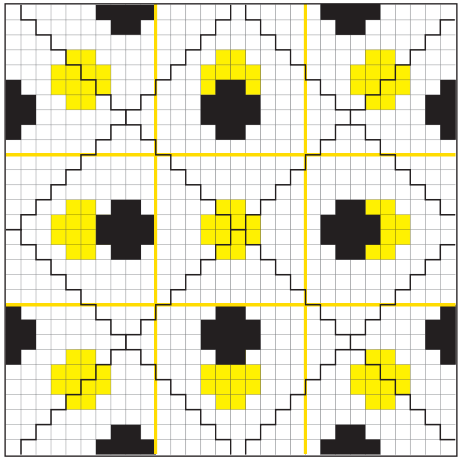


Figure 10: 45° screen dots. Dots set at a 45° can be easily created and a larger area is screened by simply lining up screen tiles.

2.1.3.1 Line Screens

Firstly, the dot shape is what makes line screens different from conventional screens. The lines begin in the highlight area as small dots, then change to elongated ellipses that grow into lines. If lines were used instead of dots in conventional screening, the printed image would not have any advantages. On the contrary, line screens are more clearly visible than dot screens in individual separations.
Line screens do have the great advantage that two colors with a 90° angle can be overprinted without creating a color shift. The four screen angles 0°, 90°, 45° and 135° can therefore be used for the four standard process colors.
In the overprint, there is no comparison between line screens generated in this way and the screens described so far. They do not create offset rosettes, but instead produce smooth color prints. The absence of the typical offset rosette also ensures better detail reproduction. They also have almost the same dot gain as conventional screens (see Chapter 7.2 Dot Gain in Print). In contrast to first-generation frequency-modulated screening, line screening does not require more care in its processing than conventional screening does.
However, unlike FM screening, moirés between the screen and the original cannot be avoided.
Line screens do well in color newspaper printing, where the rosette in the coarser screens can often be very disturbing, as well as in the production of high-quality art work, where excellent smoothness in the print is possible even with relatively low screen frequencies which are easier to print.
Unfortunately, line screens are not that well suited for silk screen printing since lines tend to produce moiré more readily in this process than in other screening methods.
When using corresponding angles, the same small screen tiles can be used as with RT screens so that large-scale moirés do not occur as they do with conventional screens.

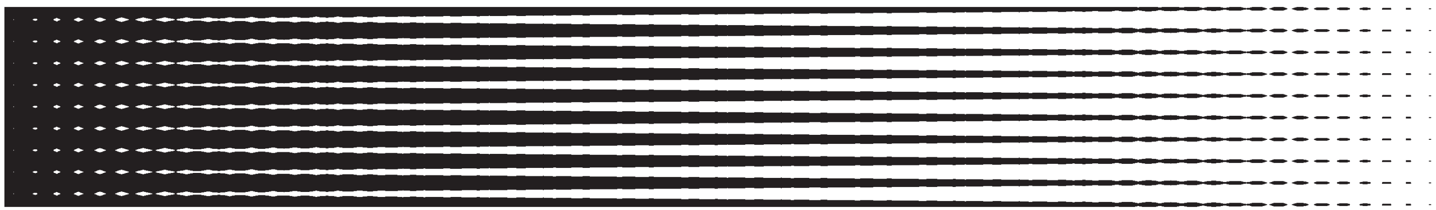


Figure 11: Example of a line screen.

2.2 Frequency-modulated Screening

Unlike the AM screens mentioned previously, frequency-modulated or FM screens are made up of a multitude of small, finely distributed dots. As the tonal value increases, the number of dots also increases until they touch each other and eventually blend in together. What changes in this screening method, therefore, is mainly the frequency.
To learn more about what factors should be taken into consideration when using a frequency-modulated screening process, see Chapter 4.6 on Prinect Stochastic Screening and Diamond Screening.

2.2.1 Ordered Dithering

Ordered dithering[11] has mainly been used for laser and inkjet printers (see the next chapter 2.2.2). The individual laser dots are distributed as finely as possible in a mostly orderly pattern, as you can see in the following example. Regular patterns also occur that appear disturbing in various tonal values. The dots are not distributed well enough for further processing, with an extremely long border line appearing between the colored and white elements. As described in Chapter 7 on screens in print, errors occur mainly at the borders of screen dots as a result of dot gain in print. For that reason, screen dots should be placed as compactly as possible to minimize the size of the border line as much as possible.
Though quick and easy to generate, reproduction quality is limited with the dithering method. It has now lost its practical significance, although some modern screens still contain dither algorithms.

2.2.2 Error Diffusion

As well as other FM screens, several kinds of error diffusion are also used for inkjet printers. These methods are primarily algorithmic. They decide whether a pixel will be set or not by comparing the current pixel with some type of dot matrix and by taking into account the adjacent pixels.
Usually, intermediate tints are approximated by distributing white and solid pixels. Each of these pixels will give you a difference to the nominal tonal value, and you are basically making an 'error' that you are attempting to rectify. This principle will be explained briefly using the classic Floyd-Steinberg filter.
The 'errors' that originate when four adjacent pixels are screened are added up with the statistic weightings shown in the following diagram. In this procedure, the current pixel density, marked by an asterisk, is added up with the statistical weighting of 16 (the sum of the other statistical weightings) and divided by the sum of all statistical weightings. The result is then compared with a threshold value and if the result is larger than the threshold, the pixel is then exposed. It is not exposed if the result is smaller or equal to the threshold.
Of course, this method only calculates those adjacent pixels that are actually set.
The 'errors' that were made when each pixel was set continue to diffuse (hence error diffusion) until the current pixel is corrected.
This method tends to create artifacts[13] in an image, with the flaws depending

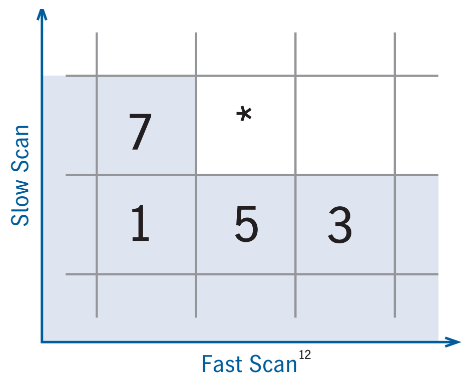


Figure 13: Statistical weighting in fast scan and slow scan directions using error diffusion.

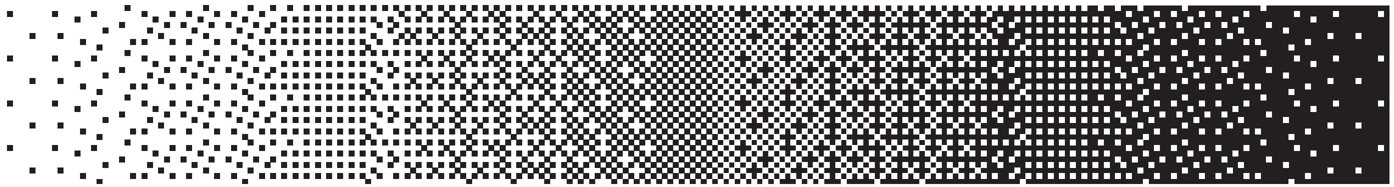


Figure 12: Example of ordered dithering (vignette from 0 % to 100 %; enlarged)

on the image. The statistical weights can be varied at random to avoid this from happening, but then you are creating relatively uneven tints in your image. The various error diffusion methods are very popular for screening in inkjet printers, despite several disadvantages, in particular the time-consuming mathematical computations.

2.2.3 Random Screening or 1st Generation FM Screening

FM screens suitable for printing need to be generated as quickly and easily as possible. They must not have any artifacts and should also be easily printable. The ordered dithering and error diffusion methods are therefore not suitable.
Progress in computer technology has provided the answer to this. Screen tiles were chosen, as described in the previous chapters, and filled with quasi random screens. These screen tiles are then rowed together and repeated, exactly as with AM screening. The art lay in choosing the right size and content (random screening) for the tiles so that no repeating structures are apparent to the naked eye.

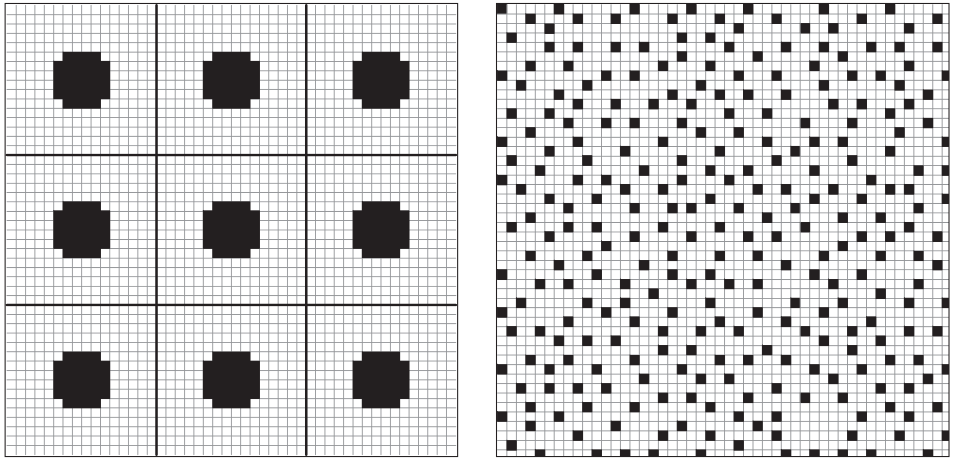


Figure 14: Comparison of standard AM screen dots and random screens (schematic) for 12.5 % coverage.

Diamond Screening from Heidelberg is one of the first representatives of this new generation of FM screens. With this method, outstanding detail definition could be achieved. As with all FM screens, the usual offset rosettes that are so disturbing do not appear with this process, but instead the result can best be compared to a color photograph.

Diamond Screening should not be regarded as the final stage of development, and is currently thought of as one of the ‘first generation’ of random screens.

2.2.4 2nd Generation FM Screening

Satin Screening and its successor Prinect Stochastic Screening are second-generation FM screens. They differ fundamentally from the first generation. The most striking difference can be seen in the medium ink coverage ranges by worm-like dot groupings. The significantly enhanced smoothness in the overprint achieved by Prinect Stochastic Screening in particular is perfectly comparable with that of conventional screens, making it suitable for motifs for which smoothness is an important factor.
The stronger bias towards grouping reduces dot gain when printing, making further processing easier and more stable than with 1st generation FM screens.

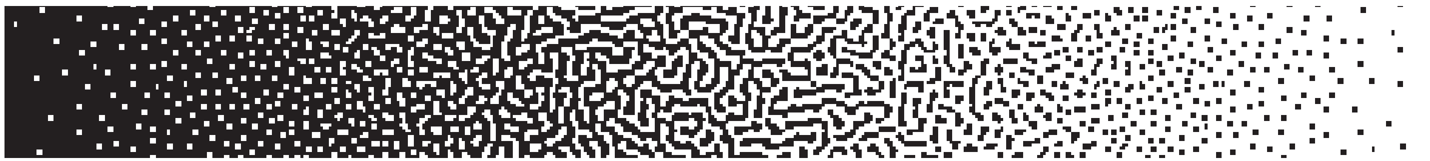


Figure 15: Example of a second-generation FM screen (continuous vignette).

Figure 16: Example of a first-generation FM screen.

2.3 Hybrid screening

Hybrid screening combines conventional screening in the mid-tone range and frequency-modulated screening in the highlights and shadows. In the mid-tones, there is no difference between Prinect Hybrid Screening and the well-known AM screens. As the tonal values become lighter, the screen dots become smaller at first, as usual, until they reach a pre-specified minimum size. From then onwards, whole screen dots disappear according to a quasi random algorithm and the transition from an amplitude-modulated to a frequency-modulated screen is complete.
As the tonal values become darker, the screen dots become ever larger, as usual, and the 'holes' between them ever smaller. Once the holes become smaller than a minimum size, whole holes then disappear according to a quasi random algorithm in a similar process to that for the light tonal ranges.
The hybrid screens solve one of the dilemmas of conventional printing. As screen frequency increases, the screen dots in the highlights become so small that some of them disappear, leading to a tonal range with unstable print behavior. The holes in the shadows behave in a similar way. This means that detail is lost in the highlights and shadows. The increased dot gain in the midrange, however, can now be relatively well mastered using calibration.
For every process, there is a minimum dot size that can be processed stably and without disappearance. The adjacent table shows the minimum tonal value, depending on the screen frequency and minimum dot size, at which stable printing conditions can be achieved. If the process allows stable dots from 20 µ upwards in size, the smaller screen dots may disappear with conventional AM screens, e. g. at 300 lpi (120 l/cm), dots become smaller than 20 µ and therefore unstable below a tonal value of 5.6 %.
Using dots with a defined minimum size also ensures stable printing in the highlights and shadows, so that the full print range can be covered. The minimum dot size can be set in stages. The quasi random distribution ensures that the highlights and shadows also appear relatively smooth and prevents any impression of coarse screening such as would occur if the dots were arranged regularly.
Hybrid screening combines the smoothness of ultra-fine screens with good printability. Like FM screening, it also produces excellent detail definition. The fineness of the screen also makes moirés with the image content unlikely.
A further advantage of hybrid screening is its scalability. Both the screen frequency and the minimum dot size can be adapted to the prevailing printing conditions.
In short, hybrid screens combine the advantages of conventional and frequency-modulated screens.

Dot sizes

Minimum dot size	Screen frequency	Unreliable printing range
20µ	150 lpi (60 l/cm)	< 1.4 %
20µ	200 lpi (80 l/cm)	< 2.5 %
20µ	300 lpi (120 l/cm)	< 5.6 %
30µ	150 lpi (60 l/cm)	< 3.1 %
30µ	200 lpi (80 l/cm)	< 5.6 %
30µ	300 lpi (120 l/cm)	< 12.5 %

Table 2: Unstable printing ranges depending on screen frequency and minimum stable dot size.

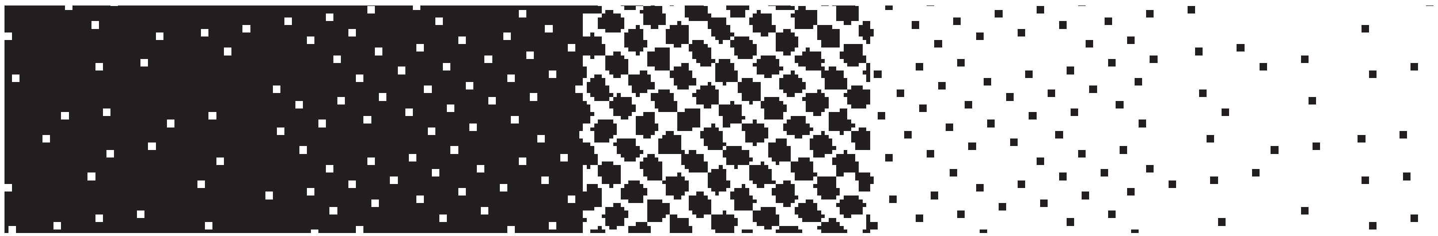


Figure 17: Example of a hybrid screen (enlarged). The step wedge contains tints of 2 %, 5 %, 50 %, 95 %, and 98 %. The smallest screen dots measure exactly 2 x 2 pixels and are distributed in a quasi random pattern.

3 Screening Technologies

This chapter deals with the technical implementation and approximation of the screening methods described so far. Dot shapes can be defined through mathematical functions that are then transformed to matrices in a RIP. Every screening technology described in this book saves screening information as matrices.

There are two basic methods:

1. The threshold matrix[14]
2. The lookup table.

In the first method, threshold values are saved in a matrix and compared with the tonal value of the image at the corresponding position. For a round-square screen dot, the adjacent shape is produced. The threshold matrix – also known as a dot matrix – is shaped like a mountain.

If the tonal value of the original is greater than the reference value in the matrix, the relevant pixel is inked, otherwise it is not inked. When this comparison-based operation is performed, the dot matrix appears to have section planes through it. In the graphics below, these section planes are shown for a light tone, a mid-tone and the shadows.

Heidelberg's screening technologies are based on this threshold matrix method. With lookup tables, a bitmap is saved for every possible tonal value level. Screening is done by simply selecting the appropriate level for the tonal value from the memory and outputting the bitmap directly.

Figure 18: Diagram of a threshold matrix. Threshold values are stored in the matrix and produce approximately this shape in the case of a round-square dot.

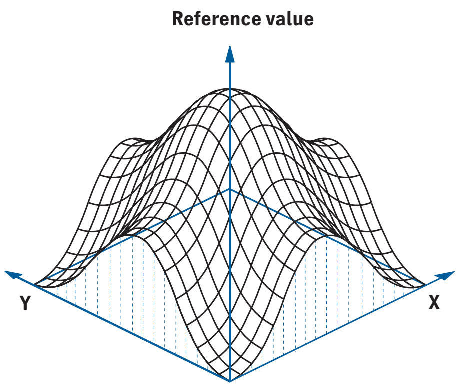
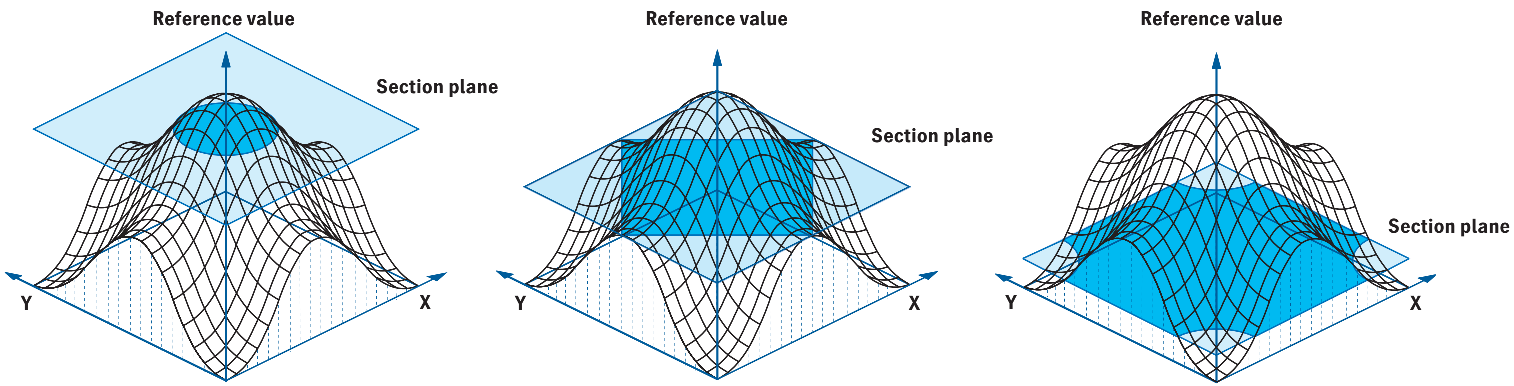


Figure 19: Diagram of section planes in the highlights, mid-tones and shadows. These are formed in the dot matrix during screening by means of comparison-based operations.



3.1 Single-Cell Screening

Single-cell screening was the only way to create screens at angles in PostScript Level 1. It will be covered here only because it is the simplest way of explaining certain principles. PostScript Level 2 and PostScript 3 brought enhancements that will be described briefly after we cover HQS Screening.

Single-cell screening is the most basic form of rational screening.

As already mentioned, rotated screen dots must be constructed into the imagesetter's pixel matrix. This is done by using the next possible screen angle and next possible screen frequency where the corners of the screen dots fall on whole imagesetter pixels (see Figure 20).

A larger screen tile is then formed based on the individual screen dots, known as screen meshes or screen cells. The screen is seamlessly constructed by placing these tiles side by side (see Figure 21).

Single-cell screening supports only rough stepping of screen angles and screen frequencies. It is particularly difficult to approximate the irrational angles of conventional screening. Even if the example below only has a deviation of 1°, it is enough to create significantly visible moiré in the overprint. The deviation in screen angle and the different screen frequency of the color separations both contribute to moiré (see sections 2.1.1.2 and 2.1.1.3). This is a problem for color reproduction in particular because there are only very few combinations that have usable overprint properties. For example, it is only possible to create a small subset in the RT screening method described below. It is practically impossible to create conventional screens.

As far as we know, these single-cell screens are no longer used. When this simple PostScript screening method emerged, high-quality screening processes such as the RT and IS screening methods described below had long been in existence.

Figure 20: PostScript Level 1 screen cell.

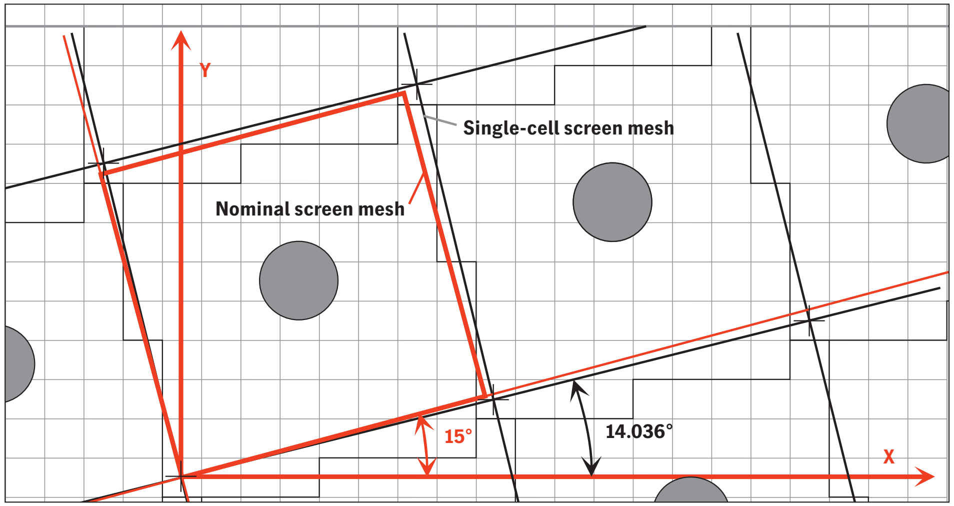
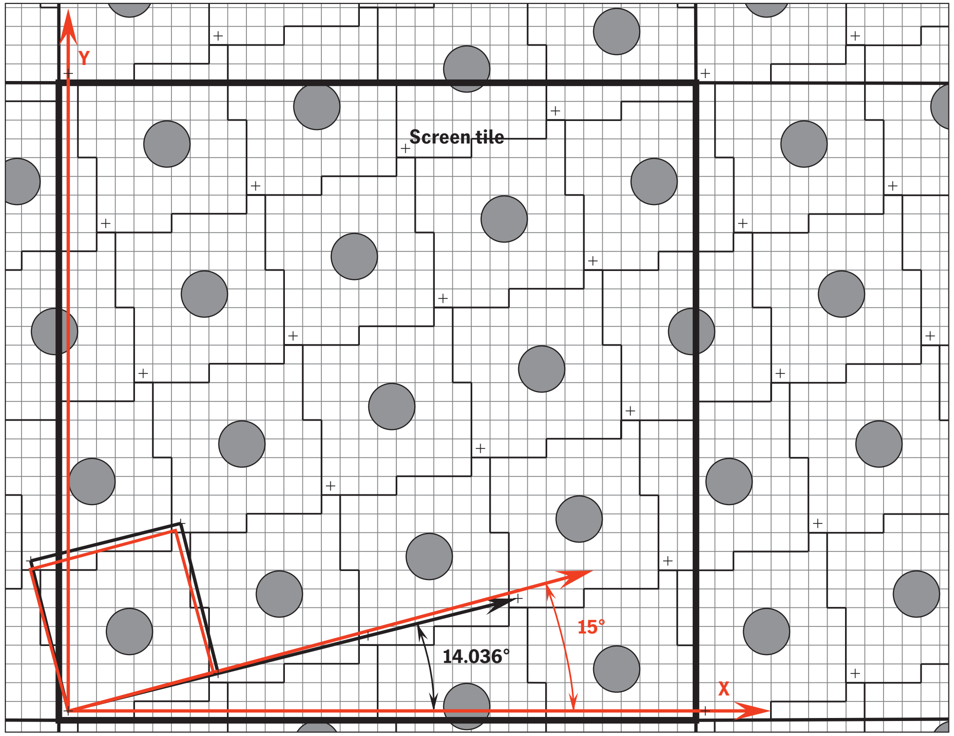


Figure 21: Single-cell screen tile.



3.2 RT Screening

The attempt to recreate the angles of conventional screens digitally was the starting point for the development of RT screening. For cost reasons, its evolution was shaped by the need to make do with a minimum of memory. This resulted in a screening technology in its own right that has its own special advantages over conventional screening. RT screening was the first rational screening method and the first ever digital screening process. The term ‘RT’ stands for ‘rational tangent’.

Rational screening will be explained in more detail by using the 0°, 45° and 18.4° angles. Screen frequencies are chosen so that the size of three screen dots set at 0° is the same size as two diagonals of the dots set at a 45° angle. An angle of 18.4° can no longer be seen as a rational approximation of conventional screening’s 15° angle. It is actually 18.43494882292 ...°. The number is the arctangent of 1/3. The 18.4° screen dots are arranged so that three dots in one direction are followed by exactly one dot in crosswise direction.

This simple procedure can be used to create ‘tiles’ that can then be pieced together seamlessly. The size of these tiles is exactly 3 x 3 screen dots at 0°. The fourth screen angle at 71.6° (90° minus 18.4°) is then generated accordingly.

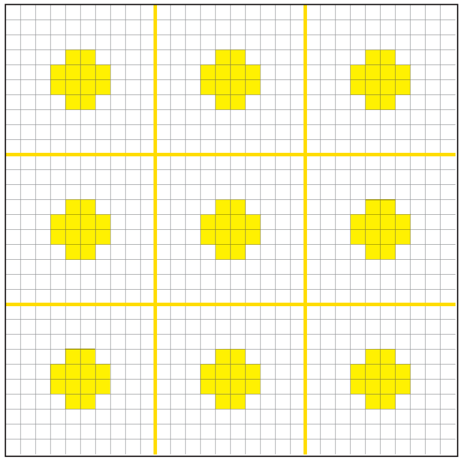


Figure 22: 0° screen dots. Dots set at a 0° angle can easily be created and a larger area is screened by simply lining up the dots.

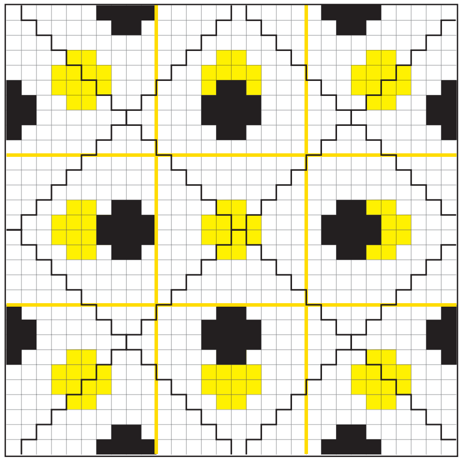


Figure 23: 45° screen dots. Dots set at a 45° can be easily created and a larger area is screened by simply lining up screen tiles.

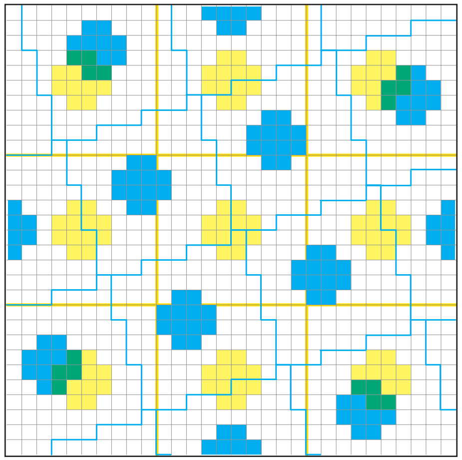


Figure 24: Diagram of an 18.4° screen tile. The pattern is repeated every three ‘0° screen dots’ in both directions.

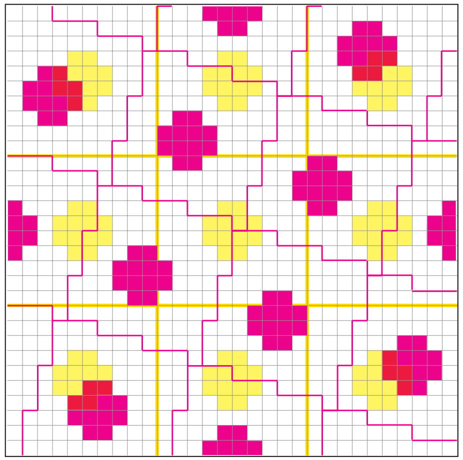


Figure 25: Diagram of a 71.6° screen tile.

Looking at the diagrams, you will notice that not only the single color separations are composed of screen tiles. You will also notice that all four color separations together are made up of screen tiles, each as large as 3 x 3 screen dots set at 0°. The great advantage of this is that, when you create an overprint, any moirés there will comprise a maximum of one period of three screen dots. Consequently, moiré will rarely be viewed as a disturbance since the period is so small.

With RT screens, unlike conventional screens, the moiré period in the overprint is as small as possible. Accuracy requirements cannot be derived mathematically, unlike with conventional screens. Our experience shows that this screening method is clearly less sensitive to misregistration. This method is a solution that can be easily implemented and that has very good overprint qualities (see Chapter 4.3 on RT Screening).

Figure 26: Overprint of all 4 RT tiles, all exactly 3 x 3 ‘0° screen dots’ in size.

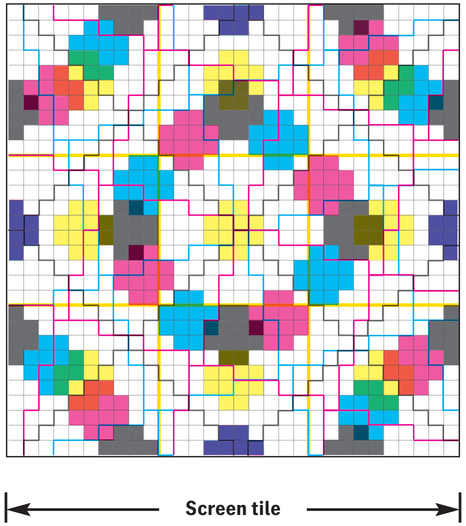
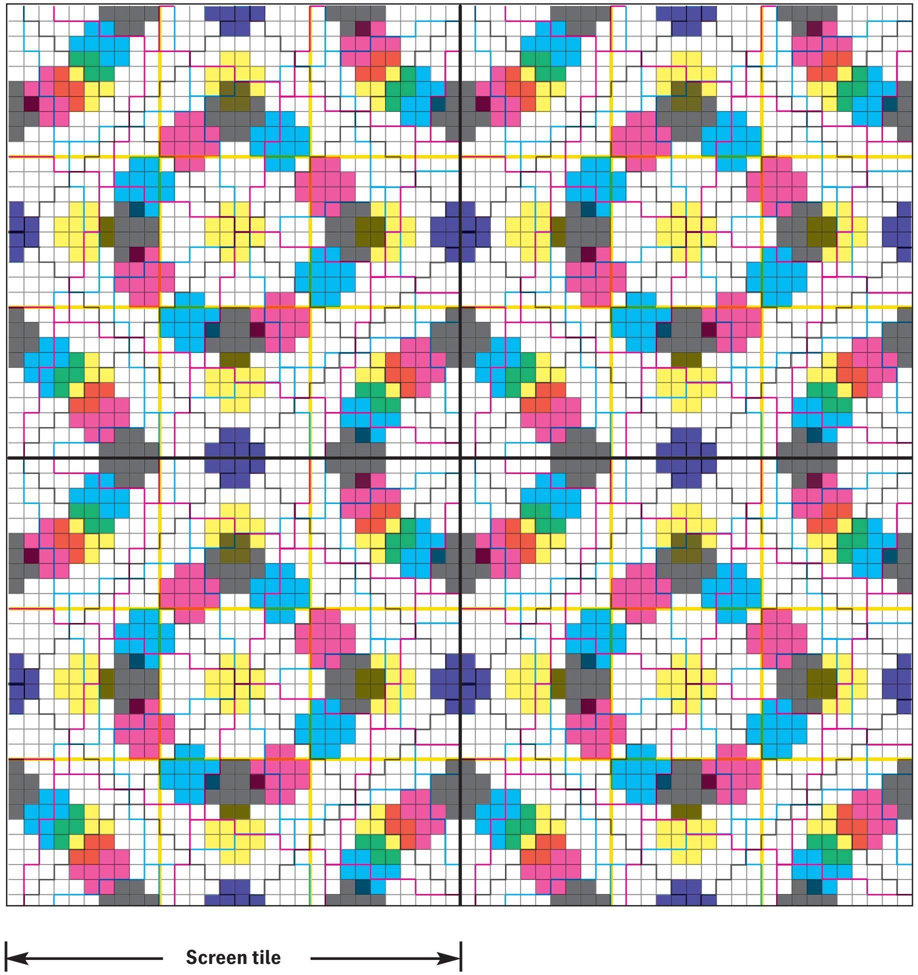


Figure 27: Adjoining screen tiles with all four colors to larger areas.



3.3 HQS Screening

HQS is short for High Quality Screening and is based on rational screening technology. As early as 1991, HQS allowed a very close approximation of conventional screens in terms of both screen frequencies and screen angles. This improvement was achieved by combining n x n screen dots into a single unit known as a supercell, with only the corners of this unit falling on whole imagesetter pixels.
This supercell screening allows a relatively close approximation of screen angles and screen frequencies. The supercells are then placed together to form a screen tile, similar to the example used in the chapter on 'Single-cell Screening'. When composing an HQS screen tile in this way, the supercell is the equivalent of one screen dot in single-cell screening (Figure 20). Because screen tiles can become quite large in this process, they are not shown here graphically.
This supercell technology enables the precision of the screens to be significantly enhanced. With this greater precision, however, comes a massive increase in memory requirements for the screen tiles. This means the screen tiles are no longer suitable.
Mathematics can offer a solution to this problem. The fact that every supercell can be converted into a same-sized rectangle known as a screen brick can be mathematically proven. The supercells often contain additional redundancies[15] that can be removed to further reduce memory requirements.
A screen is then made up of these bricks (see Figure 29). This is not done by simply placing the bricks one on top of the other as with square screen tiles but by adjoining them in a staggered pattern like the bricks of a wall. The bricks come in a range of very different shapes. The most common is a very elongated bar shape. Address computations therefore rarely have to be done.
In summation, it can be said that relatively good screen angle and screen frequency approximations are possible with small, easy-to-process screen bricks as well.

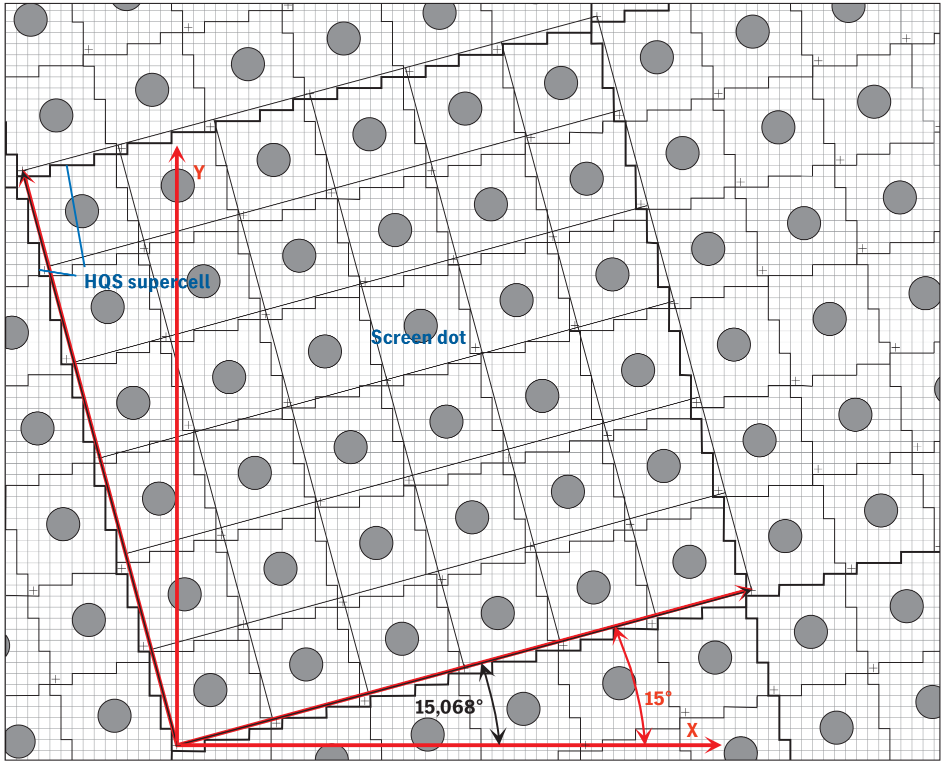
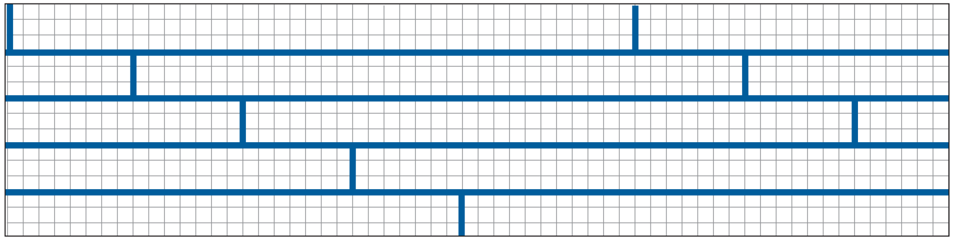


Figure 28: HQS supercell. The nominal screen mesh and the screen cell that was actually generated match up very well.

In HQS, all angles typically have slightly different screen frequencies. As a result, moiré in the overprint is a decisive criterion to remember when selecting suitable supercells for the color print. For this reason, a program was developed to calculate screen angle/screen frequency combinations without any disturbing moiré in the overprint.
The generation of HQS supercells causes slightly different ratios between the real screen angles and frequencies to occur for different nominal screen frequencies. In practice, this means that the overprint properties depend somewhat on the screen frequency. HQS and the RT screening method described above use supercells made from several screen dots. They are enhancements of the single-cell screening method described at the start.

Figure 29: HQS screen 'brick'.



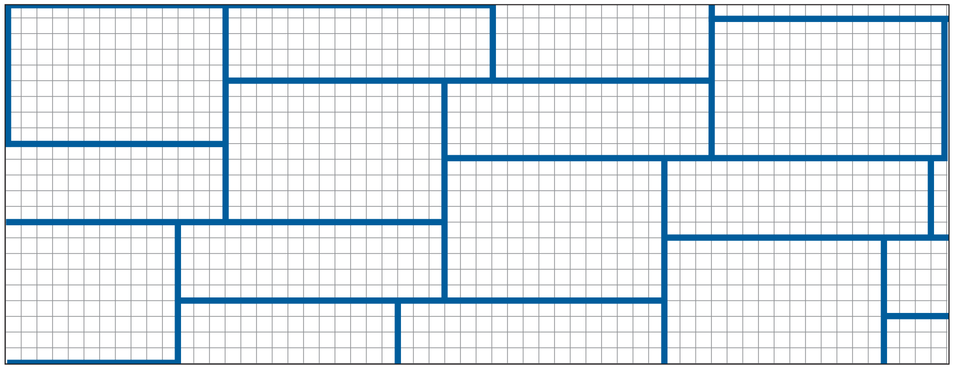


Figure 30: PostScript 16-tile screening method. Address computation in the RIP is much more complex with this method than with the screen bricks of the HQS method.

3.4 Further Supercell Screens

Several new screen types are described in PostScript 3™ and PDF (PostScript Language Reference Third Edition, ISBN 0-201-37922-8). A few of these are still based on single-cell screening (see Chapter 3.1) and the better screens are based on supercell screening which we just mentioned in the previous chapter. Screen tiles are saved in some screening methods, but this requires quite a lot of memory. The most complex screen, the Halftone Type 16, is on a par with an HQS screen with regard to its screen angles and screen frequencies. There is no advantage over HQS, and calculating a threshold matrix is more laborious. The supercell is broken down into two large rectangles of different sizes that are placed seamlessly side by side (see Figure 30). With Halftone Type 16, Adobe has opened the world of supercell technology to RIP manufacturers who do not have their own screening technology.
Considerable HQS know-how also lies behind the generation of high-quality threshold matrices with suitable geometric relationships and extremely smooth, uniform screen dots. There is no PostScript or PDF screening method that produces better quality results than HQS.

3.5 IS Technology

The rational screening methods discussed so far (as also used by other manufacturers) can only approximate irrational angles. As a result, only certain screen angles and frequencies can be generated by them, a factor which imposes restrictions on quality as well. IS screening has made cutting-edge technology available to PostScript RIPs. This screening method is used to create extremely precise screen angles and screen frequencies. IS stands for 'irrational screening'.

IS technology was originally implemented in hardware. For a long time now, though, it has only been supplied as a software implementation.

The two different implementations achieve practically the same results for screen angles and screen frequencies, but the algorithms used to calculate the screens are very different. The implementation in software benefits from more compact screen dots and smoother individual separations.

Here we will look at the classic hardware implementation to provide a better understanding of the principles involved.

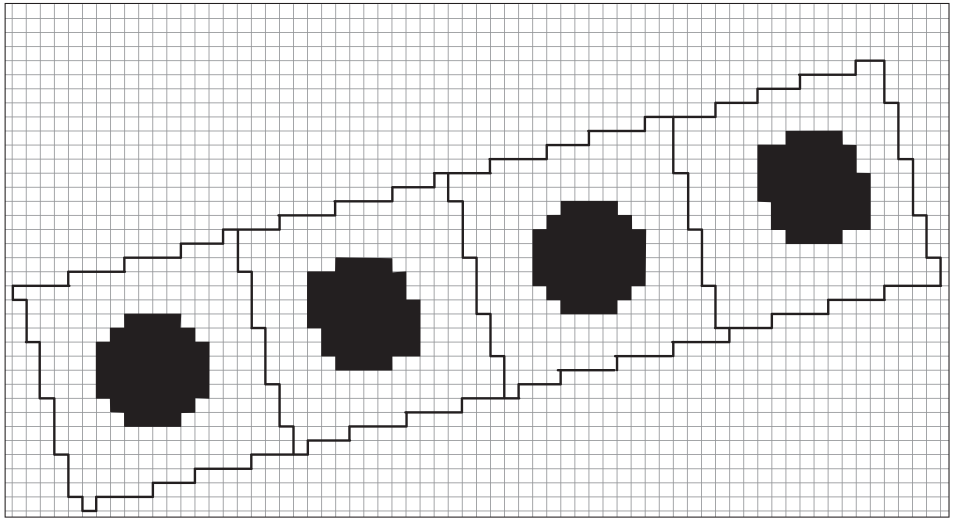


Figure 31: IS screen dots set at an angle of 15°. The sequences involved in IS screening are irregular and do not repeat themselves.

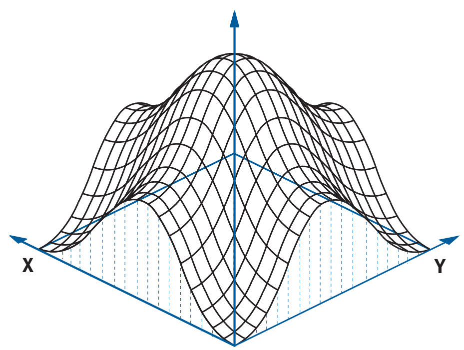


Figure 32: Diagram of a dot matrix. A matrix with an edge length of 128 elements in both x and y directions stores threshold values that produce more or less this form with round-square dots.

3.5.1 Classic IS Implementation in Hardware

Unlike the steps used in rational screening, a 15° angle can't simply be created by going three steps forward and one step to the side. Instead, the sequences involved in creating IS screen dots are irregular and do not repeat themselves.

The starting point for creating a screen is a threshold matrix consisting of, for example, 128 x 128 elements and containing one or more dot matrices. The individual screens are generated by transforming the coordinates from the imagesetter coordinate system into the mainly rotated coordinate system of the dot matrix (see Figure 33: shown in blue).

This is done in the following way. With one set of coordinates defined as the starting point, the address increments[16] are added up very accurately in x and y directions, and in this way the entry points are calculated for the dot matrix (see Figure 33: dux, duy). The threshold value stored in the dot matrix is compared to the tonal value found in the image, and depending on the results of this comparison, the relevant imagesetter pixel is set. This produces the horizontal section planes through the dot matrix described earlier.

If the limit of the screen cell – i.e. the dot matrix – is reached in this

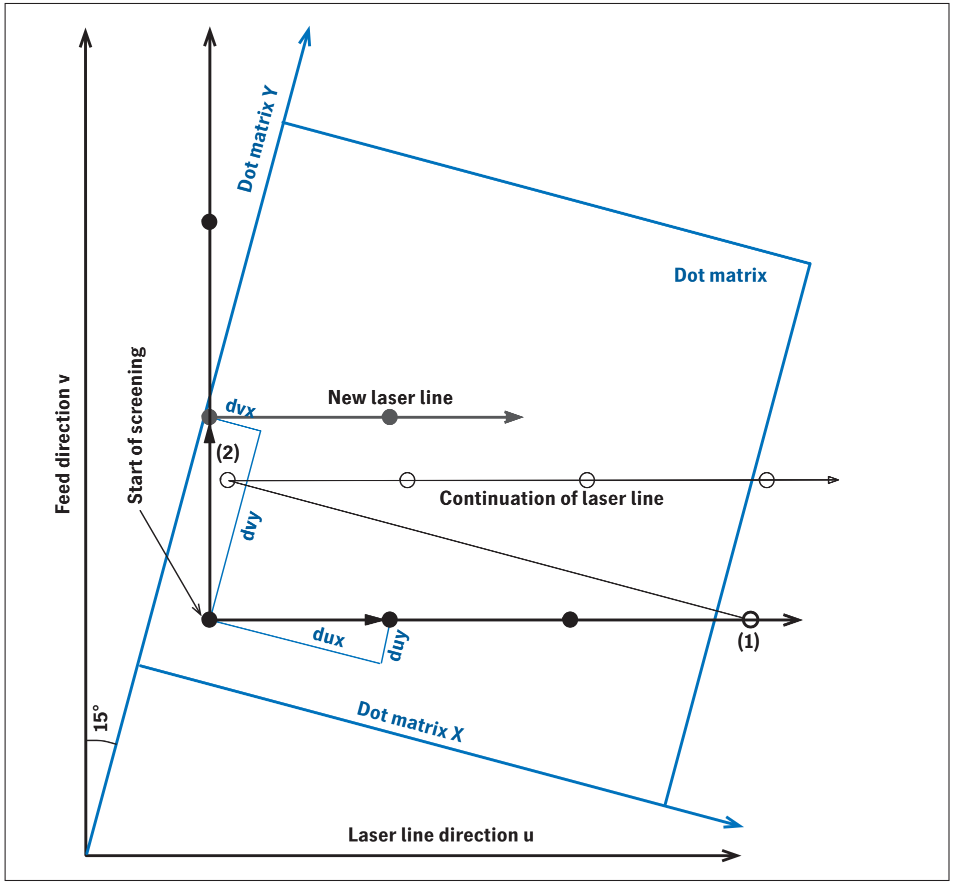


Figure 33: Transformation of coordinates in the RIP. Details can be found in the text.

calculation (see Figure 33: (1)), the overflowing bit is simply cut off and the rest of the address is then automatically used as the new entry point (see Figure 33: (2)). This step can be repeated as often as desired. At the end of a row, the starting point of the new row is calculated by adding the relevant address steps (see Figure 33: dvx, dvy) to the starting point of the previous row.
The RIP does not address each element in the dot matrix in a run. For the 15° angle shown in the example, the calculation produces different addresses for each run. With angles like 0° and 45°, the addresses are usually the same every time. Different threshold values are also linked to different addresses. With irrational screening, therefore, different digital representations are generated for the same tonal value for each individual screen dot. Special hardware is needed here because the calculations must be generated quickly and yet must be exact. This hardware is a RIP that calculates the dot matrix coordinates 'on-the-fly'[17].
IS screening gives you a screen frequency that is accurate to ± 0.000000015 and a maximum angle error of ± 0.0000012°. In other words, with an imagesetter resolution of 2540 dpi (1000 l/cm), a systematic positional deviation of just one imagesetter pixel would only occur with offset plates of 80 m x 80 m.

The level of inaccuracy found in supercell processes when approximating to conventional screens is greater by several factors of ten.
Implementing this process in software would be too slow even with today's computers.

3.5.2 Modern IS Implementation in Software

The software solution for irrational screening, referred to below as 'soft IS', is one in a long line of technical innovations by Heidelberg.
This development followed the general trend of replacing 'special hardware' with software. A major benefit for the user is the cost saving on special screening hardware. Performance also increases with each new generation of computers and has long been far superior to that of screening hardware. A 500 MHz PC was therefore able to achieve roughly the same screening performance as the Delta® Tower.
The classic (hardware-based) IS implementation algorithm is complex and requires numerous computing operations for each imagesetter pixel. Rational screens on the other hand use a very simple algorithm and can therefore be processed much faster. Even the most cutting-edge computers cannot make up for this fundamental difference in speed.
The rapid processing of rational screens can be attributed to the use of pre-calculated screen tiles. These contain the required screens with the corresponding screen frequency and angle already set, thus eliminating the need for the complex address computations required with the hardware-based IS method.
Soft IS combines the benefits of both methods – the high accuracy of the IS technology on the one hand and the rapid processing of rational screens on the other.
In order to harness the speed benefits, key elements of soft IS are based on the HQS method previously described. The required irrational screens are firstly approximated using a (rational) screen tile. An error investigation then takes place, the aim of which is to determine the number of pixels on an imagesetter line above which the deviation between the given rational screen and the required irrational screen exceeds a pre-defined threshold. This number of imagesetter pixels can be screened at the high speeds typical of HQS. Corrective measures are then performed, after which screening is resumed at high speed. This method provides a level of precision comparable to that of the hardware method and better than a device pixel.
In themselves, the corrective measures are much more complex than hardware-based IS screening. However, because they only have to be performed very rarely, they are not a dominant feature of the process. The method can best be described using an example: Imagine you have a normal sheet of graph paper with grid squares measuring 1 mm, but need one with squares measuring 1.005 mm. For the first few squares, the deviation is certainly negligible, but after 200 squares the error amounts to a whole square. A simple corrective measure would be to make one square in every 200 double the size. Then the number of squares would add up again and the error would be compensated. However, the double-width squares would be disturbing. Alternatively, you could add, for example, one square with a width of 1.05 mm instead of 1 mm after every 10 squares. Then these corrective measures would no longer be noticeable.
The corrective measures of soft IS work in a very similar way.
In this way, a few crucial changes eliminate the limitations of HQS and allow full compatibility with the screen angles and frequencies of IS hardware screening.
Soft IS has also been setting new quality standards for a long time. The individual color separations are significantly smoother. Thanks to further enhancements, much greater screen frequencies can now be achieved.
The soft IS method speaks for itself. It delivers the best possible quality for the minimum outlay.

3.6 Tonal Value Levels and Calibration

It isn't hard to see the advantages in having many imagesetter pixels per screen dot. An example of this:
A screen dot made of 8 x 8 pixels is created if a 300 lpi screen (120 l/cm) is exposed with an imagesetter resolution of 2540 dpi (1000 l/cm). Only 8 x 8 + 1 = 65 different tonal value levels can be displayed using such a screen dot, which is by no means enough to show a vignette smoothly in an ink coverage going from 0 % to 100 %. Breaks, or banding[18], especially in the dark end of the scale, are very noticeable.
Because the human eye is very sensitive to differences in dark areas, approximately 1000 tonal value levels are needed to display a smooth vignette, at least if it is constructed of even tints. See Tips and Tricks in Chapter 8 for more details.
Multidot technology is used to achieve the greatest number of tonal value levels possible. Even with the old hardware IS screening method, the dot matrix memory was not loaded with just one dot, but with several. Each differs slightly from the next, and the result is that adjacent screen dots also vary slightly. The difference is so small that it is not detected by the naked eye since the eye only perceives the mid-range tonal value of neighboring screen dots.
With the introduction of HQS and soft IS screening, multidot technology was refined still further.
The selective use of this technology can ensure the availability of more than 1000 tonal value levels at all times and in all implementations. However, in most cases, only 256 of these tonal values (8 bits) can be used due to the data being processed in a PDF or PostScript Interpreter. The only exception to this is smooth shading, which is described in Chapter 8.2.
Despite these limitations, the quality of smooth shading vignettes for linearization and calibration benefits substantially from a stock of well over 256 tonal value levels in the screening process (see Chapters 6.6 and 7.3).
With standard implementation in PostScript and PDF, mapping in linearization and calibration is 8 bits to 8 bits i.e. 256 input tonal values are mapped to 256 output tonal values.
During this process, it is often the case that not all input values can be mapped to an output value. As a result, values are lost and banding occurs in the vignettes (see Chapter 8.2).
To avoid this, a higher number of levels, e. g. 12 bits, is required on the output side. If mapping during calibration is from 8 bits to 12 bits, all input levels are practically always mapped to different output levels. Due to the higher resolution in the dot matrix, all output levels are then reproduced differently so that all 256 PostScript/PDF tonal value levels are always available, resulting in a noticeably smoother tonal value scale.

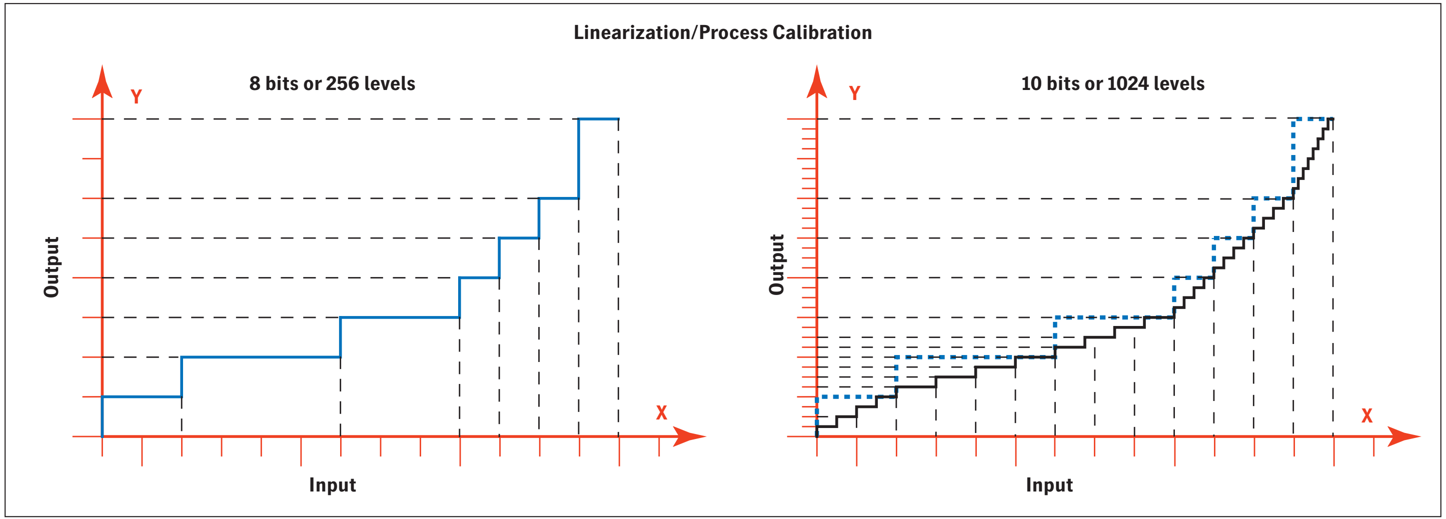


Figure 34: Comparison of a calibration with 8-bit and 10-bit resolution. A calibration with 12-bit resolution cannot be represented graphically because of its exceptional fineness.

4 Screen Systems and Dots

This chapter is intended as a reference for the various screen systems and dot shapes. It does not build upon the previous chapters, so it is possible that some of the details from earlier sections are repeated here.

4.1 Screen Systems

4.1.1 AM Screen Systems

In color reproduction, the aim is to achieve the very best overprint properties. Color printing is more than just printing four individual colors with different screens.
There are only a few combinations of angles and screen frequencies that guarantee good results so it is important to hit on exactly these combinations.
We use the term 'screen system' when talking about such a combination.
An AM screen system has at least four screens, mostly with different angles. The corresponding screen frequencies may also differ. The relationship of the screens to one another is fixed and they are selected to minimize moiré in the overprint.
There is a choice of, in most cases, several dot shapes that work optimally for each screen system.

Different screen frequencies can be chosen for each screen system. The value shown in the user interface is a nominal value. The actual screen frequencies mostly deviate slightly from this value. In the case of Heidelberg screen systems, with the exception of HQS, the following applies: Irrespective of the absolute screen frequency, the relationship between the screen frequencies that belong together and the different color separations is constant. This means that the overprint properties do not depend on the screen frequency, but only on the system used.
The screen systems of other providers work differently by approximating the conventional irrational screen angles using rational angles. This means the overprint properties are dependent on the screen frequency selected.
Some RIPs allow users to enter arbitrary screen angles and screen frequencies. This data is then approximated to a greater or lesser degree of accuracy (see Chapter 2.1.1.3 Accuracy Requirements and Chapter 3.1 Single-Cell Screening).
As already mentioned, only certain combinations guarantee good results in the overprint. If a user does not know precisely what he is doing and how his RIP behaves, he will not be able to produce good results.
It is clear from this that it makes no sense for users to enter arbitrary screen angles and frequencies.
The 'Document Controlled Screening' setting enables Heidelberg screening to be deactivated and Adobe internal, freely configurable screening to be activated. This makes it possible to use any screen angles and frequencies with Heidelberg RIPs. The risks and side-effects just mentioned also apply here (see Chapter 5.4.4).

4.1.2 FM Screen Systems

Screen systems are also required for FM screens. The individual separations have basically the same characteristics. The patterns are different, however, to prevent color shift.
Different FM screen systems are distinguished by their structural configuration and smallest dot sizes.

4.1.3 Screen Angle Counting Method

Screen angles were discussed in the previous chapters without explaining how they are measured. The absolute position of the angles also wasn't important in previous discussions.
The only thing that is crucial for the overprint is the relative positioning of one angle to another. This fact meant there was never a uniform standard in the past.
The zero position is almost always 12 o'clock (compass north), in line with the old DIN 16547 standard, and the counting direction clockwise. Depending on the output system, the angles may also be counted in counter-clockwise direction.
The development of digital screen proofing systems created a new scenario. To obtain a proof with the exact same screen, the platesetter must behave in the same way as the proofing system.
That is why newer Heidelberg products implement screen angles in a standardized form, irrespective of the output system.
This accords with the old DIN 16547 standard. With reference to the recto side, the zero position is 12 o'clock and the angles are counted in clockwise direction, which means it does not matter whether a page is rotated by, for example, 90° or 180° when it is being mounted on a sheet. The screen rotates along with it. These approaches always

refer to the print. In some individual cases, the user must clarify whether the system will follow the standard or be device-specific.
The current DIN-ISO 12647-1 standard is not followed for compatibility reasons. In the latest version, the angles are counted as in mathematics. The zero position is the horizontal and the counting direction is counter-clockwise.
The above rules are not valid for situations in which Heidelberg screens are deactivated, i.e. when the ‘Document Controlled Screening’ setting has been activated.
When determining the screen angles of a print in practice, the following difficulties arise:

- The ambiguity of the screen angles: With round or square dots, the 45° and 135° angles, for example, cannot be distinguished. Because of the symmetry, there are no clear-cut angles, but instead there are always two angles of equal value staggered by 90°. Elliptical dots and line screens make the process easier, as the angles between 45° and 135° can be distinguished. They have clearly defined angles that are measured in the direction of either the first dot chain[19] or the line.
- The zero position and angle counting direction may not be known.
- The ambiguity of screen counters. Some screen counters can also determine screen angles. However, they cannot distinguish between angles such as 45° and 135°, even through this might seem possible for a screen counter with a larger measuring range of 180°. Determining angles unambiguously is only possible with a magnifying glass or microscope.

A small angle star on which the positions of the angles are entered by hand has proved useful in this regard. Firstly, the user attempts to determine the position of the yellow angle, although this sometimes proves difficult because of the color’s minimal contrast. Once this angle has been determined, it acts as a reference angle for the other screen angles. These angles are entered on the star by hand to produce an overview of the angles. The zero position and angle counting direction can then also be derived from this.
The following screen systems are optimized for elliptical dots, as the angles of the dominant colors are spaced at 60° intervals from each other.
The screen systems are described in the same order as that used for the screening methods in Chapter 2, followed by an examination of the dot shapes that are suitable for each of these systems.

Figure 35: Ambiguous screen angles with round screen dots and unambiguous angles with elliptical dots.

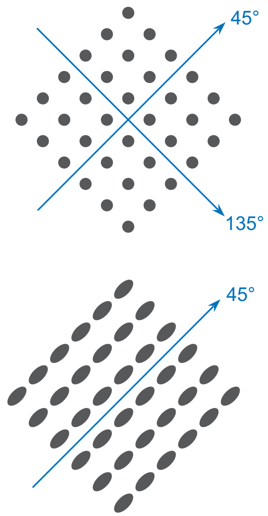
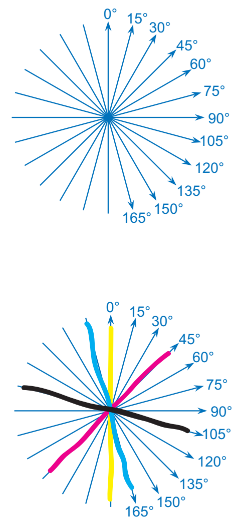


Figure 36: Screen star without and with screen angles plotted.



4.1.4 Print Examples

Colors in the overprint can seem slightly different as a result of the fundamentally different overprint properties of conventional screens (rosette formation) and frequency-modulated screens.
This cannot be avoided even with calibration of the plate output device. Further optimization of the printed result in all tonal values can only be achieved by using color management on the basis of ICC profiles. This reference book was printed intentionally without ICC profiles.

4.2 Irrational Screening (IS)

IS systems are conventional screen systems where the defining colors cyan, magenta and black are spaced at angles of 60°. This 60° interval (instead of 30°) produces better overprint results with the elliptical dot used as standard.
IS systems are not approximations, but exactly conventional screens with excellent quality. Irrational screening achieves a quality unattainable with any other screening method.

4.2.1 IS Classic

IS Classic is the classic, conventional offset screen system.
The position of the angles in this system can be seen in the diagram opposite.
As can be seen in the table of relative screen frequencies, the yellow separation at 0° is somewhat finer than the other screens. This reduces the moiré that can appear in yellow in conventional screening methods (see Chapter 2.1.1, Conventional Screening).
The angle allocation with magenta at 45° is optimized for the reproduction of skin tones. For other motifs, it may be advisable to switch the angle of magenta with that of cyan or black.
For an illustration of this system, see the print sample insert.

IS Classic Screen System

	Color	Screen angle	Relative screen frequency
	Cyan	165.0°	1.000
	Magenta	45.0°	1.000
	Yellow	0.0°	**1.061**
	Black	105.0	1.000

Table 3: Properties of the IS Classic screen system.

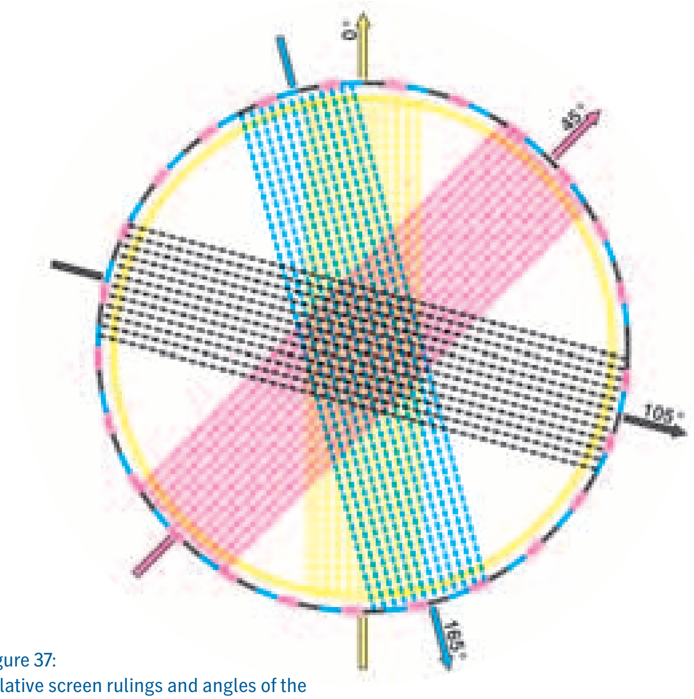
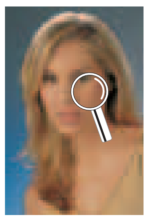
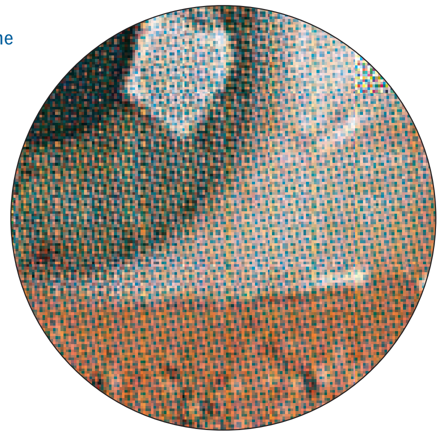


Figure 37:
Relative screen rulings and angles of the IS Classic screen system.

Figure 38:
Enlarged section from the IS Classic screen.





4.2.2 IS Y fine

The IS Y fine screen system is a further development from the classic, conventional IS Classic screen system. Yellow is generated with a much higher screen frequency in order to avoid the yellow moiré found in conventional screening. With this system, it is no longer necessary to switch the angles depending on the colors of the motif.
A further advantage is the fact that black is set at 45°. Not only does this prevent the sawtooth effect at horizontal and vertical edges, it also makes this screen system suitable for black and white printing with no need for a further angle switch.

As can be clearly seen in the table of relative screen frequencies, the yellow separation set at 0° is finer than the other screens by a factor of 1.414. Because of the large deviation in the screen frequency of yellow, color-dependent calibration is necessary for screening reasons alone.
For an illustration of this system, see the print sample insert.

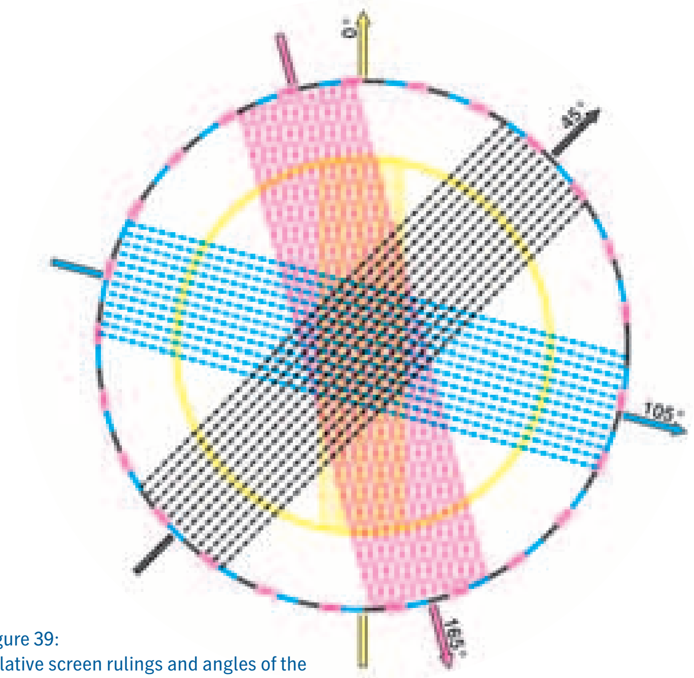
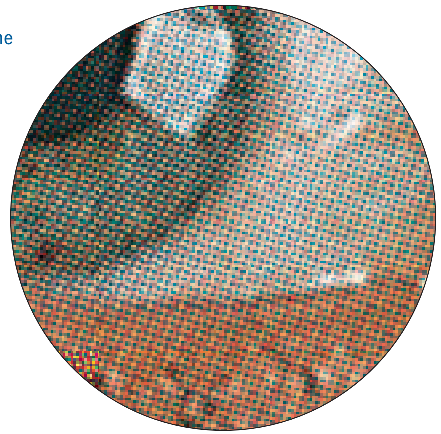


Figure 39:
Relative screen rulings and angles of the IS Y fine screen system.

Figure 40:
Enlarged section from the IS Y fine screen.



IS Y fine Screen System

	Color	Screen angle	Relative screen frequency
	Cyan	105.0°	1.000
	Magenta	165.0°	1.000
	Yellow	0.0°	**1.414**
	Black	45.0°	1.000

Table 4: Properties of the IS Y fine screen system.

4.2.3 IS Y60°

IS Y60° is a conventional screen system in which yellow is set at 60° and all colors have exactly the same screen frequency.
This screen system is more suited for flexography or silk screen printing than the IS Classic screen system. Moirés between the screen and the silk screen or screen roller that inks the flexographic form are minimized as the system does not have an angle of 0°.
A further advantage is the fact that black is set at 45° which is ideal for one-color printing.
Some customers expect printing benefits, for example with slurring and doubling, by avoiding the 0° angle and use this screen system for that reason.
However, since yellow shows up very light anyway, avoiding the 0° angle for yellow does not make any difference in screen visibility.
The table shows the allocation of colors to the screen angles and relative screen frequencies.
The angle allocation is optimized for the reproduction of skin tones. For other motifs, it may be advisable to switch the angle of magenta with that of cyan or black.

IS Y60° Screen System			
	Color	Screen angle	Relative screen frequency
	Cyan	165.0°	1.000
	Magenta	105.0°	1.000
	Yellow	60.0°	1.000
	Black	45.0°	1.000

Table 5: Properties of the IS Y60° screen system.

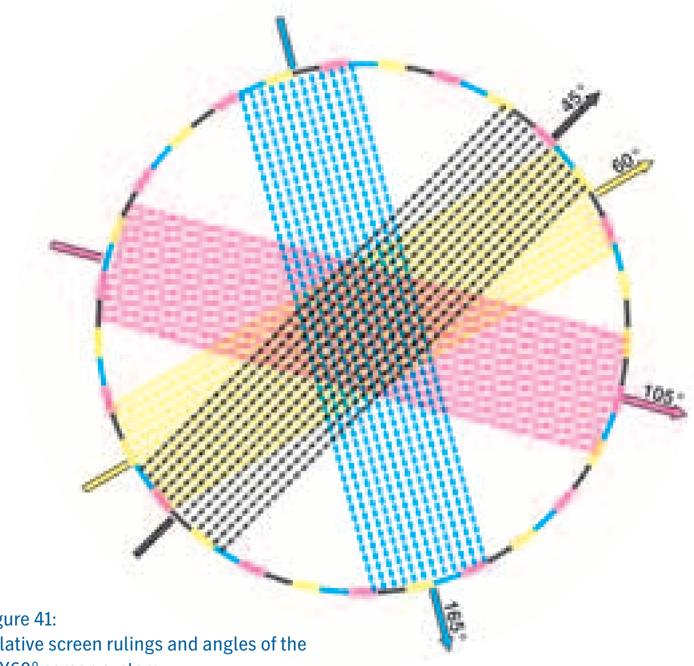
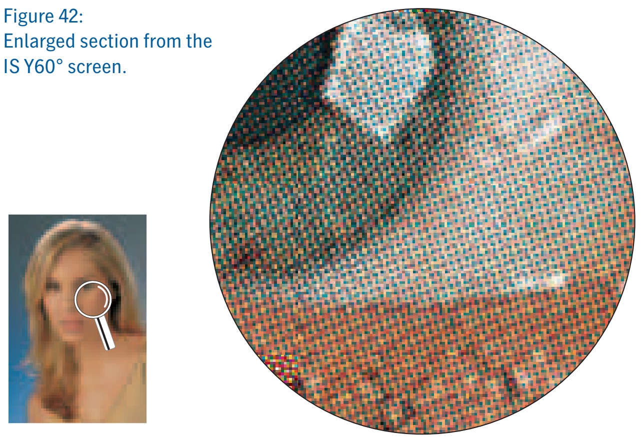


Figure 41:
Relative screen rulings and angles of the IS Y60° screen system.

Figure 42:
Enlarged section from the IS Y60° screen.



4.2.4 IS Y30°

IS Y30° is a conventional screen system in which yellow is set at 30° and all colors have exactly the same screen frequency. It is the counterpart to the IS Y60° screen system.
It is more suited for flexography or silk screen printing than the IS Classic screen system. Moirés between the screen and the silk screen or screen roller that inks the flexographic form are minimized as this screen system does not have an angle of 0°.
A further advantage is the fact that black is set at 45° which is ideal for one-color printing.
Some customers expect printing benefits, for example with slurring and doubling, by avoiding the 0° angle and use this screen system for that reason. However, since yellow shows up very light anyway, avoiding the 0° angle for yellow does not make any difference in screen visibility.

The table shows the allocation of colors to the screen angles and relative screen frequencies.
The angle allocation is optimized for the reproduction of skin tones. For other motifs, it may be advisable to switch the angle of magenta with that of cyan or black.

IS Y30° Screen System

Color	Screen angle	Relative screen frequency
Cyan	105.0°	1.000
Magenta	165.0°	1.000
Yellow	30.0°	1.000
Black	45.0°	1.000

Table 6: Properties of the IS Y30° screen system.

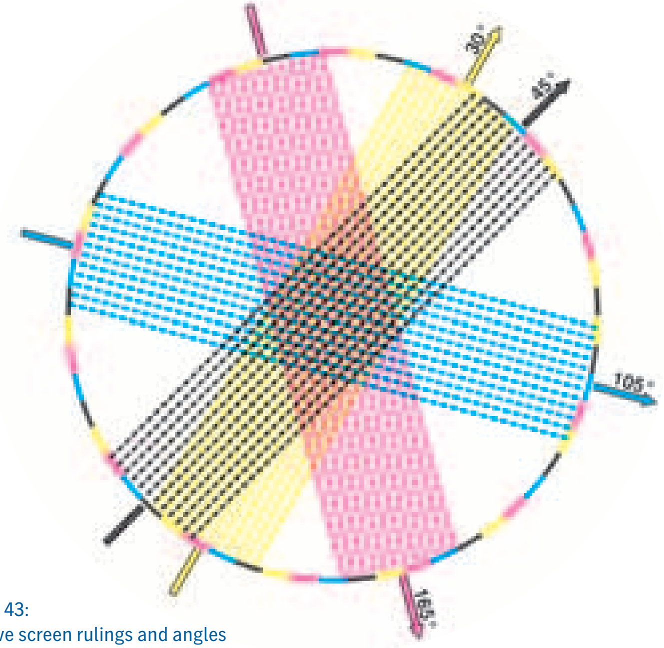
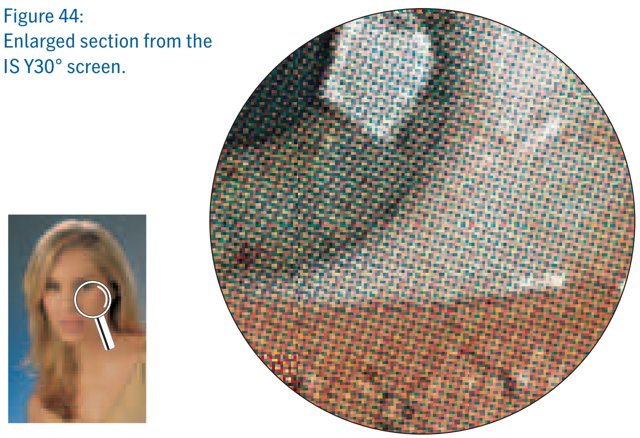


Figure 43:
Relative screen rulings and angles of the IS Y30° screen system.

Figure 44:
Enlarged section from the IS Y30° screen.



4.2.5 IS CMYK+7.5°

IS CMYK+7.5° is a conventional screen system that has been rotated by 7.5°. All colors have exactly the same screen frequency.
This screen system is extremely well-suited for conventional offset printing. It has the best overprint properties of all conventional screen systems.
It was originally developed for flexography and silk screen printing. The 7.5° rotation minimizes moiré between the screen and the silk screen or screen roller that inks the flexographic form.
For this reason, this screen system is particularly well suited for offset-gravure (OG) conversions[21].
The table and graphic shows the allocation of colors to the screen angles and relative screen frequencies.

The angle allocation is optimized for the reproduction of skin tones. For other motifs, it may be advisable to switch the angle of cyan with that of magenta or black.
For an illustration of this system, see the print sample insert.

IS CMYK+7.5° Screen System

Color	Screen angle	Relative screen frequency
Cyan	172.5°	1.000
Magenta	52.5°	1.000
Yellow	7.5°	1.000
Black	112.5°	1.000

Table 7: Properties of the IS CMYK+7.5° screen system.

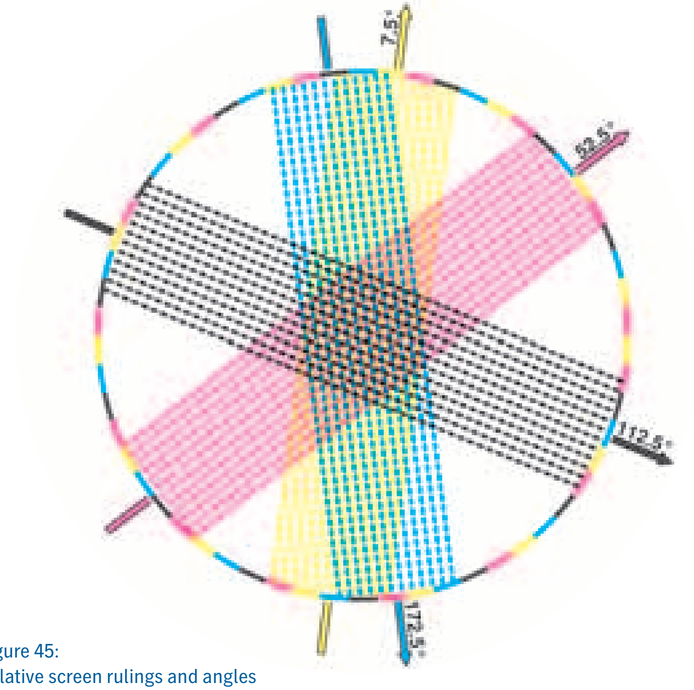


Figure 45:
Relative screen rulings and angles of the IS CMYK+7.5° screen system.

Figure 46:
Enlarged section from the IS CMYK+7.5° screen.

4.3 RT Screening

These screen systems are distinguished by the fact that all the angles have a rational tangent.

There are differences, some of them great, in the relative screen frequencies for the various color separations of these screen systems.

RT screening was developed for the first scanners and recorders that could screen electronically. However, the 'old' RT screens are by no means redundant. Because of their specific properties, they are still in use today.

4.3.1 RT Classic

An example of rational screening was described in Chapter 3.2. The overprint shows a weak, square structure instead of the usual offset rosette pattern. This weak, uniform structure produces a smoother appearance than the offset rosette.

A further advantage is the fact that black is set at 45° which is ideal for one-color printing.

The table shows the allocation of colors to the screen angles and relative screen frequencies.

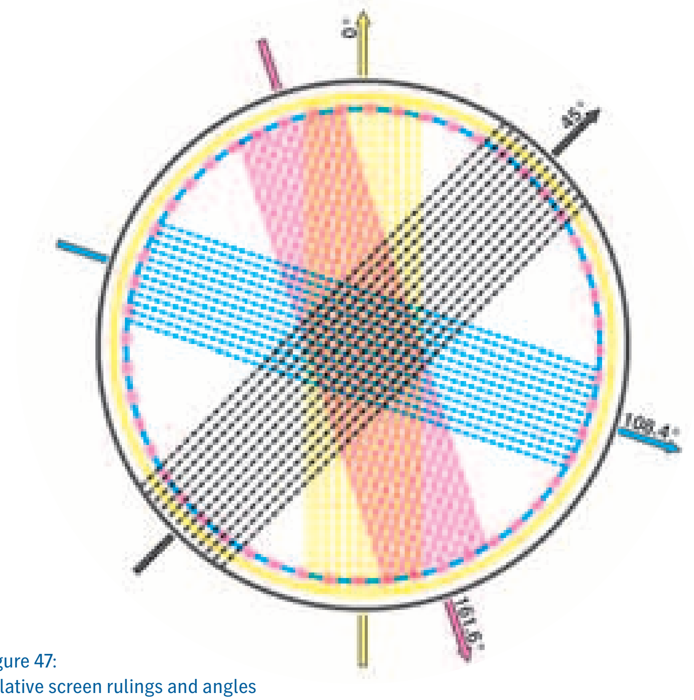


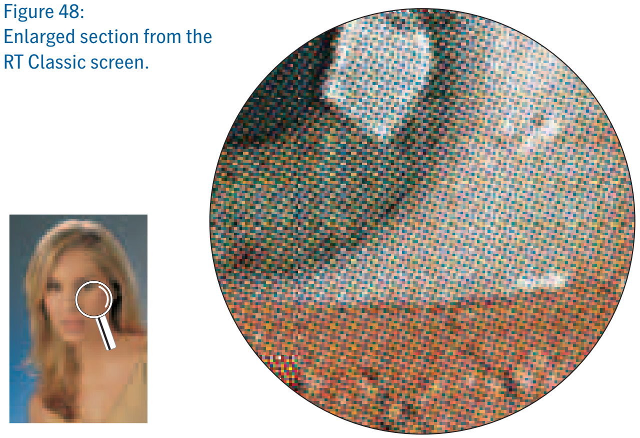
Figure 47:
Relative screen rulings and angles of the RT Classic screen system.

RT Classic Screen System

Color	Screen angle	Relative screen frequency
Cyan	108.4°	1.118
Magenta	161.6°	1.118
Yellow	0.0°	**1.061**
Black	45.0°	1.000

Table 8: Properties of the RT Classic screen system.

Figure 48:
Enlarged section from the RT Classic screen.



4.3.2 RT Y45° K fine

The RT Y45° K fine rational screen system is a further development of the RT Classic screen system. Yellow and black are set at 45°. The screen frequency of black is 1.5 times higher than that of yellow.

This results in a much smoother overprint than that achieved with conventional screens.

The graphic and table shows the allocation of colors to the screen angles and relative screen frequencies.

This screen system is extremely well-suited to all color combinations so that no motif-dependent angle switch is required.

Because of the large deviation in the screen frequency of black, color-dependent calibration is necessary for screening reasons alone.

For an illustration of this system, see the print sample insert.

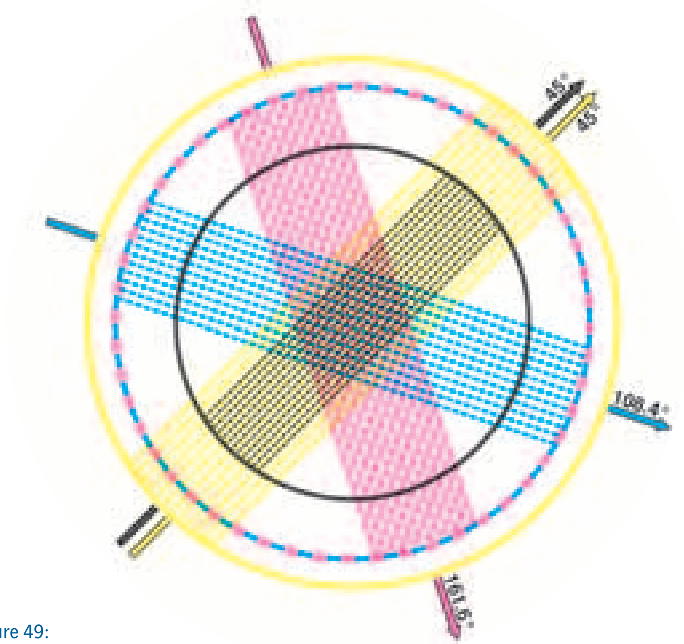


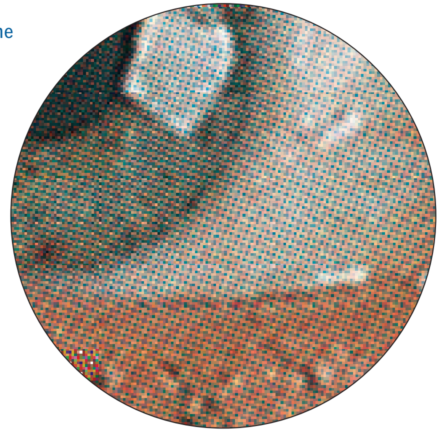
Figure 49:
Relative screen rulings and angles of the RT Y45° K fine screen system.

RT Y45° K fine Screen System

Color	Screen angle	Relative screen frequency
Cyan	108.4°	1.118
Magenta	161.6°	1.118
Yellow	45.0°	**1.000**
Black	45.0°	1.500

Table 9: Properties of the RT Y45° K fine screen system.

Figure 50:
Enlarged section from the RT Y45° K fine screen.



4.4 High Quality Screening (HQS)

High Quality Screening (HQS) is a rational screening technology that allows very close approximations of irrational angles. The required screen frequencies are also very closely approximated. The precision of the approximation varies from screen to screen. The overprint properties are influenced by these deviations.
All the IS screen systems have a counterpart in HQS. Complete implementation of the IS screen systems in software has led to HQS screen systems per se being superseded. They are still available however for compatibility reasons.

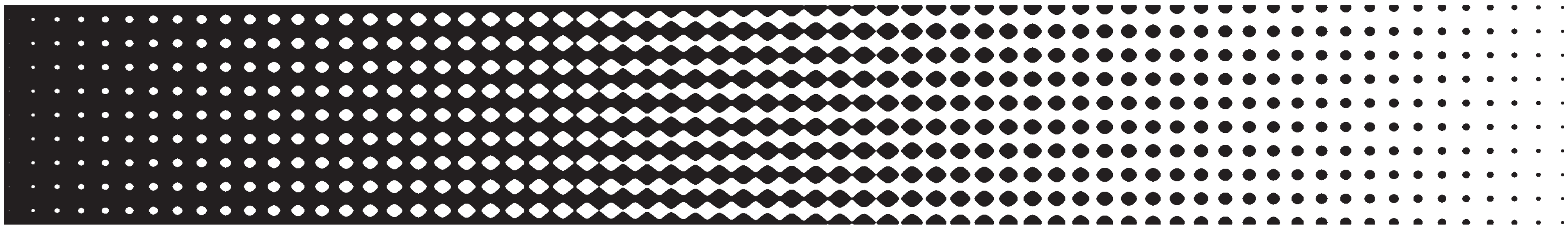
4.5 Dot Shapes

Different dot shapes are used for different purposes, and we will discuss their use in this section.
All screen dots are optimized. They are created according to design rules, so premium quality is always ensured.
For very high screen frequencies, the specific shape becomes increasingly lost, as the size of the screen cell allows only a few design possibilities.
Screen dots should have a short border line making them as compact as possible, because dot gain in print increases with the length of the border line.
During plate production, it is beneficial to image the dots with the sharpest possible border definition as this ensures better results when reproducing and printing them.
The dot shapes in the following sections can be used in all the screen systems presented earlier.

4.5.1 Elliptical Dot

Smooth Elliptical is the dot shape that is recommended for offset printing.
This dot starts off almost circular in the highlight area and then becomes increasingly elliptical. When the dots join for the first time at 44 %, the dot takes on a rhombic shape. After the dots join the second time, at 61 %, rhombic shapes are first created, then elliptical ones, and finally round holes appear again in the shadows.
As soon as neighboring screen dots touch each other, this produces a color bridge in print that leads to a tonal value jump. In the case of elliptical dots, the dot join is split into two steps, reducing the jump effect and making it easier to control with calibration (see Chapter 7.3 Process Calibration).
This is the ideal dot shape for offset printing.
The elliptical dot is also recommended for silk screen printing, letterpress printing and offset/gravure conversion.

Figure 51: Dot shape: Smooth Elliptical (enlarged).



4.5.2 Round-Square Dot

The Round-Square dot shape is the classic dot shape used in offset printing, originating from the glass engraving screen mentioned at the beginning of this book. In PostScript, this dot shape is also known as a Euclidian[22] dot.
The round-square dot begins as a virtually circular dot in the highlight area and becomes increasingly square in the midtones until it reaches the shadows, where round holes appear. The dots join together at 50 % and are slightly staggered to smooth the tonal value jump and make it easier to control with calibration.

This dot shape was frequently used for technical motifs (e. g. steel, porcelain) in which the tonal value jump caused by printing was used to increase the midtone contrast. However, it is better to set the contrast by changing the gradation curve[23] in the image editing system and to use the elliptical dot during exposure.
This dot is still used to a certain extent in routine processes. Printshops want to avoid the organizational complications involved in changing their production process, such as changing their process calibration or their quality control.

4.5.3 Round Dot

The Round dot shape was developed for flexographic printing.
This completely round dot joins at 78 %, after which pincushion-shaped holes appear.
In flexographic printing, a letterpress printing method with elastic print forms, the screen dots are squashed and, as a result, there is considerably more dot gain here than in offset printing. With this dot shape, the dots join together at a point where the dots are already smudged. The tonal value jump that normally occurs is avoided as a result of this late dot join.

Flexographic printing is mainly used for printing packaging, carrier bags, labels etc.

Figure 52: Dot shape: Round-Square (enlarged).

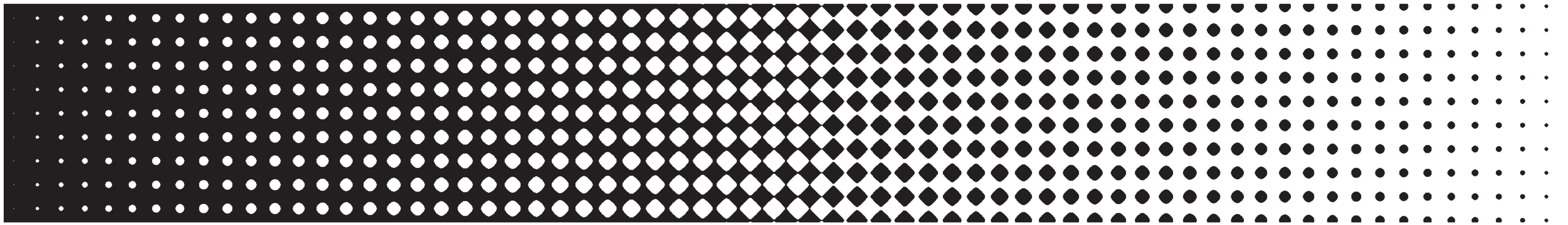
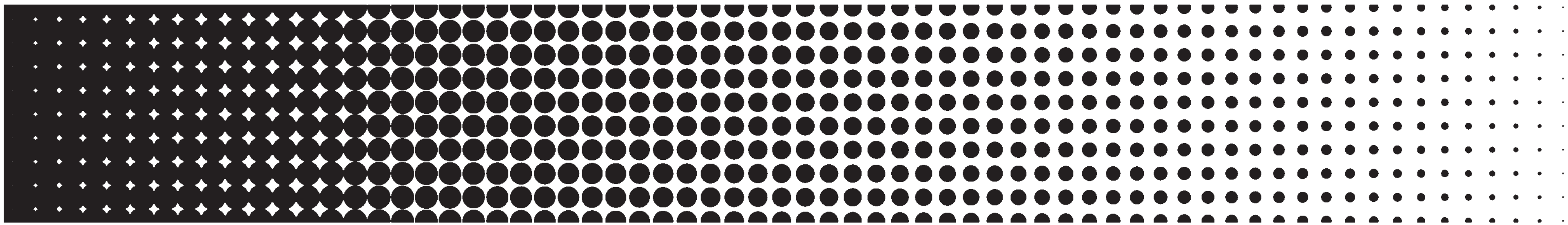


Figure 53: Dot shape: Round (enlarged).



4.6 Frequency-modulated Screening

Prinect Stochastic Screening from Heidelberg and the older Satin Screening and Diamond Screening are frequency-modulated (FM) screening methods.

Prinect Stochastic Screening is the latest development from Heidelberg. It is a second-generation FM screen that replaces the older Diamond Screening und Satin Screening methods.

All FM screens have the following properties:

As the tonal value increases, so does the number of dots and therefore the screen frequency. With a further increase in the tonal value, the dots join and merge. Several holes are left in the shadows.

The size, distribution and shape of the dots determine the type of frequency-modulated screen. They vary considerably for the different screens.

FM screens do not produce the usual offset rosette, so often a disturbing element, but instead the result can best be compared to a color photograph.

To demonstrate the excellent level of detail that Prinect Stochastic Screening provides, the same image was printed using both IS Classic and Prinect Stochastic Screening. An enlarged section appears on this page.

Another important advantage of FM screens can be seen in this example: There is no moiré between the fine, regular pattern of the textiles and the irregular print screen. FM screens are especially well-suited for technically demanding reproductions that entail many fine details such as loudspeakers, textiles, wood grains and high-resolution satellite pictures etc.

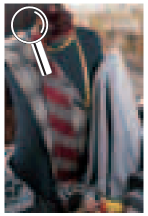
A point to note in passing: No screen system will help you subsequently remove any moirés that appears between the original and the pixel screen of a digital camera or the scanning screen of your scanner. In this case, you just have to re-digitize the original using a finer resolution.

Unlike conventional screens, FM screens are immune to color shifts caused by registration[6] fluctuations. To retain the excellent detail definition, however, care should be taken with registration. Minor misregistration is first only noticed as blurring; when it becomes larger it appears as color fringes.

With FM screens, the dot shape is an integral component of the screen. Unlike AM screens, there is no choice between e.g. elliptical and round dots.

Figure 54: Enlarged section from the AM screen (IS Classic).

Figure 55: Enlarged section from the FM screen (Prinect Stochastic II fine).



4.6.1 Prinect Stochastic Screening

Prinect Stochastic Screening is a new development, which replaces Satin Screening described in more detail in chapter 4.9.2. Not only were the algorithms for the distribution of screen dots enhanced still further, but the individual properties of the CtP devices were also taken into account. Prinect Stochastic Screening takes the benefits of Satin Screening a stage further.

A comparison demonstrates the advantages:

- Print stability was improved.
- Smoothness of the print result was enhanced.
- Possible repeating patterns were minimized.
- The minimum dot size can be set. These FM screens are therefore scalable in a similar way to Prinect Hybrid Screening, making them easy to adapt to the prevailing print conditions.

Prinect Stochastic Screening systems are scalable from various perspectives:

- The general character of the screen is determined by the screen system selected.
- The size of the smallest dots can be set over several stages without this affecting the midtones. The smallest dot can therefore be adapted to the print conditions.
- Using this technique for the screen settings means the screens can then still be coarsened by doubling or tripling the individual pixels and therefore the whole structure.

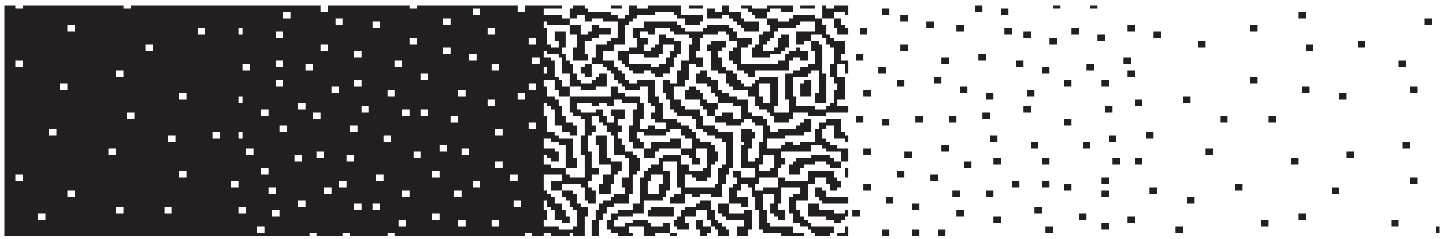
The last two options can be set through the user interface by selecting the dot size.

Unlike earlier FM implementations, Prinect Stochastic Screening produces a smoothness comparable to that of conventional screens – even for tints. Prinect Stochastic Screening delivers a virtually photorealistic reproduction and excellent detail definition. The print result is comparable to a color photograph in appearance.

With Prinect Stochastic Screening, the dot gain in print is still somewhat greater than with conventional screens. Process calibration is therefore recommended.

As a general rule of thumb, the print conditions should be carefully monitored and kept constant.

Figure 56: Prinect Stochastic Screening. The step wedge contains tints of 2 %, 5 %, 50 %, 95 % and 98 %. The smallest screen dots measure exactly 2 x 2 imagesetter pixels and the midtones are more densely clustered (enlarged).



4.6.1.1 Prinect Stochastic Screening II fine

Prinect Stochastic Screening II fine is a further development from the Prinect Stochastic fine screen system. The innovative feature of this system is the ability to scale the smallest dots in the highlights and shadows. If a minimum dot size of 2 x 2 imagesetter pixels is selected, the two screens are identical. At 2540 dpi (1000 l/cm), this corresponds to a dot size of 20 μ. Prinect Stochastic Screening fine is still available for the time being for compatibility reasons. However, it is recommended that users change to Prinect Stochastic Screening II fine at a suitable opportunity.
The screen dots start in the highlight area as small dots of a defined size. In the midtones, these then merge to form fine 'worm-like' structures. In the shadows, small holes of a defined size are generated.
The minimum dot or hole size can be set to e. g. 2 x 2 imagesetter pixels or 2 x 3 imagesetter pixels, which is shown as 20 μ or 24 μ at 2540 dpi (1000 l/cm) on the user interface.
The defined and scalable size of the dots in the highlights and shadows ensures stable printing of these areas. The scalability allows better adaptation to different printing stocks. In the midtone area, the structure is selected so that this area too is printed particularly smoothly and stably, regardless of the smallest dot size selected.
Prinect Stochastic Screening II fine is especially well-suited to artwork and high-quality commercial printing. With larger dot sizes, the screen is also suitable for flexographic printing and particularly silk screen printing, as no moiré can occur with the silk screen. In this application, its functions overlap to some extent with those of the Prinect Stochastic Screening II medium screen system described below.
For an illustration of this system, see the print sample insert.

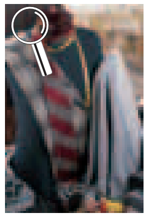
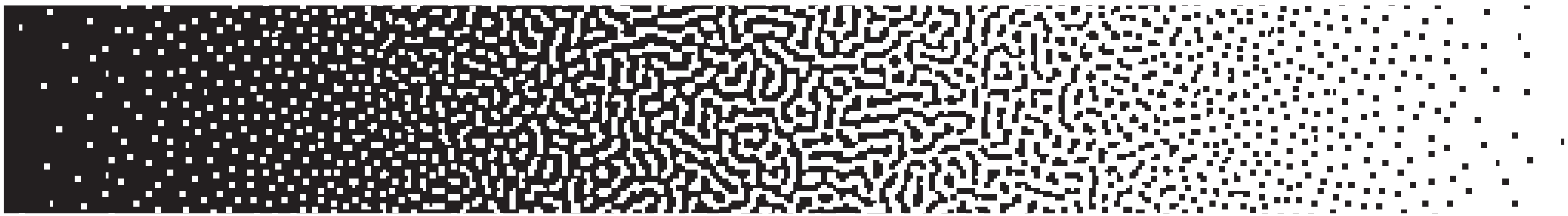


Figure 58: Enlarged section from the Prinect Stochastic Screening II fine screen.

Figure 57: Prinect Stochastic II fine with 20 μ dot size (enlarged).



4.6.1.2 Prinect Stochastic Screening II medium

Prinect Stochastic Screening II medium is a further development from the Prinect Stochastic medium screen system. The innovative feature of this system is the ability to scale the smallest dots in the highlights and shadows. If a maximum dot size of 3 x 3 imagesetter pixels is selected, the two screens are identical. At 2540 dpi (1000 l/cm), this corresponds to a dot size of 30 µ. Prinect Stochastic Screening medium is still available for the time being for compatibility reasons. However, it is recommended that users change to Prinect Stochastic Screening II medium at a suitable opportunity.

The screen dots start in the highlight area as small dots of a defined size. In the midtones, these then merge to form ‘worm-like’ structures. In the shadows, small holes of a defined size are generated.

The minimum dot or hole size can be set to e. g. 2 x 3 imagesetter pixels or 3 x 3 imagesetter pixels, which is shown as 24 µ or 30 µ at 2540 dpi (1000 l/cm) on the user interface.

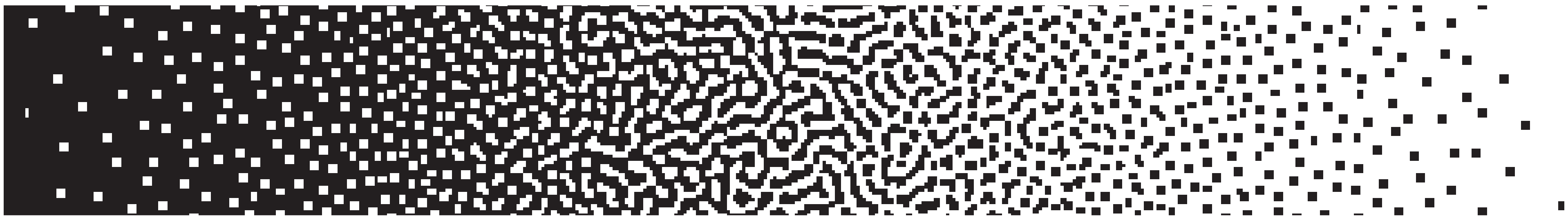
The defined and scalable size of the dots in the highlights and shadows ensures stable printing of these areas. The scalability allows better adaptation to different printing stocks. In the mid-tone area, the structure is selected so that the print is noticeably smoother than with the Satin medium system. This area is independent of the smallest dot size selected and prints particularly stably.

Compared to Prinect Stochastic II fine, the structures in the midtones are coarser in all cases. Prinect Stochastic Screening II medium is therefore especially well-suited to newspaper printing and work on uncoated[24] paper. It is also suitable for flexographic printing and particularly silk screen printing, as no moiré can occur with the silk screen. The applications of Prinect Stochastic Screening II fine and medium overlap to some extent.

For an illustration of this system, see the print sample insert.

Figure 60: Enlarged section from the Prinect Stochastic Screening II medium screen.

Figure 59: Prinect Stochastic II medium with 30 µ minimum dot size (enlarged).



4.7 Prinect Hybrid Screening

Prinect Hybrid Screening is a logical further development from Heidelberg IS technology. It is the ideal fusion of conventional and frequency-modulated screens, combining the benefits of both methods.

In the highlight area, Prinect Hybrid Screening has screen dots of a defined size that are distributed in a quasi random pattern and can be set to between 4 and 9 imagesetter pixels.

As the tonal value increases, further dots are set forming a conventional, amplitude-modulated screen in the midtones. In the shadows, holes of a defined size are also distributed in a quasi random pattern.

This screen allows extremely high screen frequencies to be printed without the dots in the highlights disappearing or the shadows filling in.

Until recently, fine screens in particular were highly prone to dot disappearance in the highlight area.

Dots measuring 20 μ can still be printed reliably with the thermal printing plates most commonly used. Smaller dots are often unstable. With a 300 lpi screen (120 l/cm), the critical 20 μ threshold is 5 % ink coverage, and with a 400 lpi screen (160 l/cm), the critical range extends to 10 % (see also Chapter 2.3 Prinect Hybrid Screening and Chapter 7.4 Selecting Screen Frequencies). With other print processes, the critical threshold can even be higher leading to a significant further increase in the critical printing range.

The greater dot gain in the midtones when working with higher screen frequencies can be effectively controlled with process calibration (see also Chapter 6.6/ 7.3 Linearization/Process Calibration).

Prinect Hybrid Screening therefore allows extremely fine screens to be printed reliably. The print result achieved with these screen frequencies is outstandingly smooth and the offset rosette is also no longer visible.

The print samples demonstrate the superb detail definition of Prinect Hybrid Screening compared to a conventional screen.

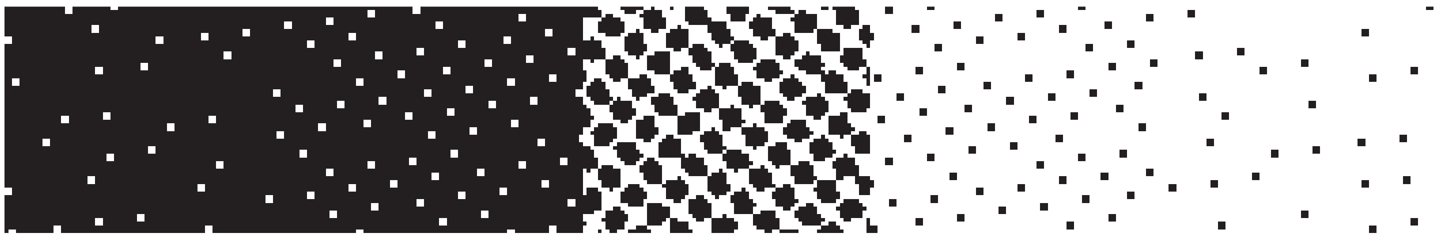


Figure 61: Prinect Hybrid Screening with Smooth Elliptical dot shape (300 dpi/120l/cm) (enlarged). The step wedge contains tints of 2 %, 5 %, 50 %, 95 % and 98 %. The smallest screen dots measure exactly 2 x 2 pixels and are distributed in a quasi random pattern.

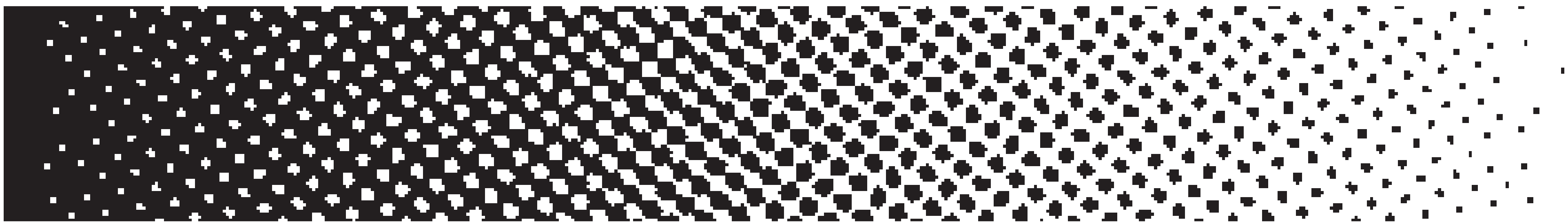


Figure 62: Prinect Hybrid Screening (300 dpi/120l/cm) with 20 μ minimum dot size (enlarged).

A further advantage of Prinect Hybrid Screening is its scalability. Both the screen frequency and the minimum dot size can be adapted to the prevailing print conditions.
The following table shows the angle allocation for Prinect Hybrid Screening. It is pre-angled by 7.5°. The angle for black is close to the preferred 45° for particularly good reproduction of right-angled edges. The 45° interval between magenta and yellow is optimized for the reproduction of skin tones. For other motifs, it may be advisable to switch the angle of magenta with that of cyan or black.
The pre-angling also minimizes moirés between the original and the screen. Unlike with Prinect Stochastic Screening, moirés between the original and the screen cannot be avoided entirely, but they occur only very seldom because the screen frequency is usually high.
Prinect Hybrid Screening is especially well-suited to high-quality commercial printing and artwork. Processing is also straightforward and uncomplicated. It is practically the ideal method for offset printing.
For an illustration of this system, see the print sample insert.

Figure 63: Tints with 5 % and 2 % in Prinect Hybrid Screening with the Smooth Elliptical dot shape (300 dpi/120 l/cm) and minimum dot shapes of 20 μ, 22 μ, 24 μ, 26 μ, 28 μ and 30 μ.

Prinect Hybrid Screening

Color	Screen angle	Relative screen frequency
Cyan	112.5°	1.000
Magenta	172.5°	1.000
Yellow	37.5°	**1.061**
Black	52.5°	1.000

Table 10: Properties of the Prinect Hybrid Screening system.

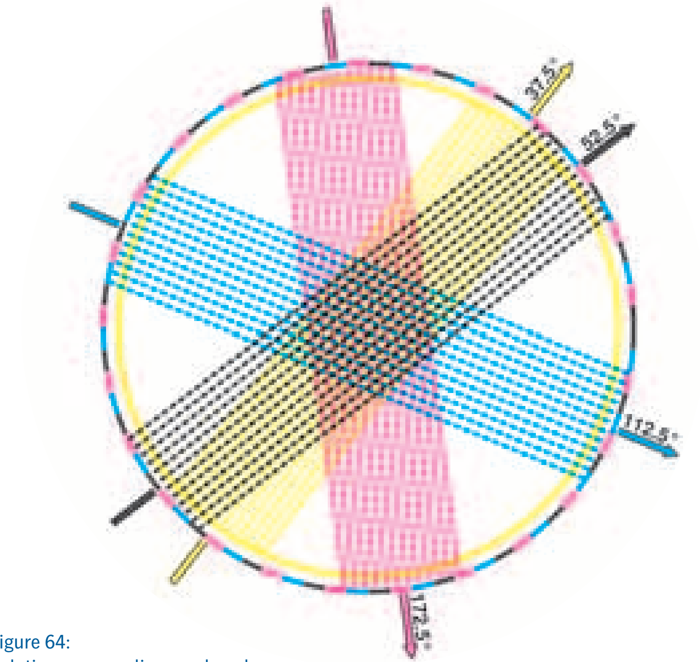


Figure 64:
Relative screen rulings and angles of the Prinect Hybrid Screening system.

Figure 65:
Enlarged section from the Prinect Hybrid Screening system screen.

4.8 Megadot Screening

The Megadot screen is a special AM screen that cannot be compared to the other screens described so far. It is mainly a line screen that uses a fine screen with an inverted round dot for black.

Megadot screens do not generate offset rosettes and produce very smooth overprints compared to conventional screens. If either cyan or magenta is predominant, the line screen can be more clearly visible than a dot screen.

Megadot screening is well-suited for commercial printing and artwork, because it delivers a smooth print result even with relatively low screen frequencies, making printing easier.

The line screens used have a slightly greater dot gain in print than conventional screens. The fine screen for black has a correspondingly high dot gain, just like the RT Y45° K fine screen system. This fact should be remembered in calibration (see also Chapter 6.6/7.3 Linearization/Process Calibration).

Unlike Prinect Stochastic Screening, however, moirés between the original and the screen cannot be avoided in Megadot.

4.8.1 Megadot CM 0°

Cyan and magenta are set at 0° and 90° in this screen system. Yellow is set at 45° and black is generated as a fine screen at 45° as well. This screen system is characterized by its particularly smooth overprints.

4.8.1 Megadot CM 45°

Megadot CM 45° is a variation of the Megadot screen just described. It is also essentially a line screen, with the defining colors cyan and magenta set at 45° and 135°. This screen is less visible in a single separation since the human eye perceives horizontal and vertical lines better than it perceives diagonal ones. Yellow is set at 0° and a fine screen set at 45° is used for black. The overprint, however, is not quite as smooth as that produced with the Megadot CM 0° screen.

4.8.3 Megadot Dot Shapes

Megadot and Megadot Flexo are the two dot shapes available in Megadot screen systems.

The Megadot starts off as a small round dot in the highlight area, then turns into an elongated ellipse and continues on to become line-shaped. Small round holes appear again in the shadows. This dot shape was developed mainly for offset printing, although it is suited for other printing processes as well.

Megadot Flexo is an inverted Megadot. It begins as a small round dot in the highlight area and then turns into an elongated, inverse ellipse; in other words, a line dot with side supports. Once again, small round holes develop in the shadows. This dot shape was developed for flexographic printing.

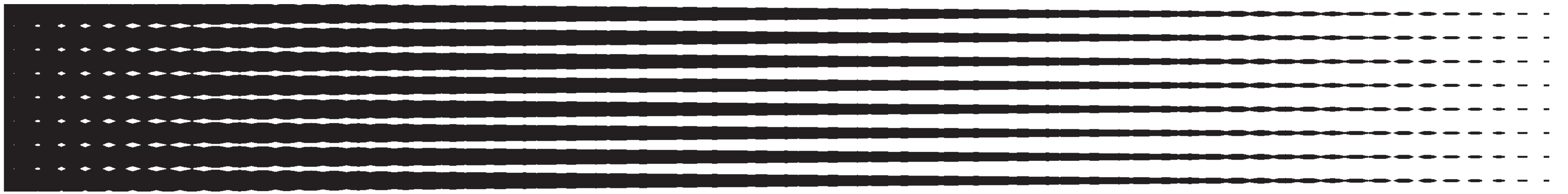


Figure 66: Megadot dot shape for cyan, magenta and yellow (enlarged).

4.8.4 Megadot Plus

Megadot Plus is a follow-on development from Megadot offering even more benefits.
Unlike all other amplitude-modulated screening methods, the screen meshes take the form of parallelograms rather than squares. The line-like screen dots grow along the longer side of the parallelograms. The following diagrams show Megadot Plus screen examples in the highlight, midtone and shadow areas. The table opposite shows the allocation of colors to screen angles and relative screen frequencies.
Megadot Plus appears approximately 50% finer than conventional screening in the overprint and approximately 20 % finer than its predecessor Megadot.

For example, a Megadot Plus screen of 100 lpi (40 l/cm) is about as fine as a conventional screen of 150 lpi (60 l/cm), and a Megadot Plus screen of 150 lpi (60 l/cm) is about as fine as a Megadot screen of 175 lpi (70 l/cm). Of course, Megadot Plus has all the positive features of the older Megadot system outlined in the previous section, and more benefits besides. Offset rosettes do not occur. The fine line structure causes the dot gain in print to be greater than with conventional screens. For this reason, process calibration is recommended.

Megadot Plus Screen System

Color	Screen angle	Relative screen frequency
Cyan	90°	1.000
Magenta	0.0°	1.000
Yellow	45°	**0.943**
Black	135°	**0.943**

Table 11: Properties of the Megadot Plus screen system.

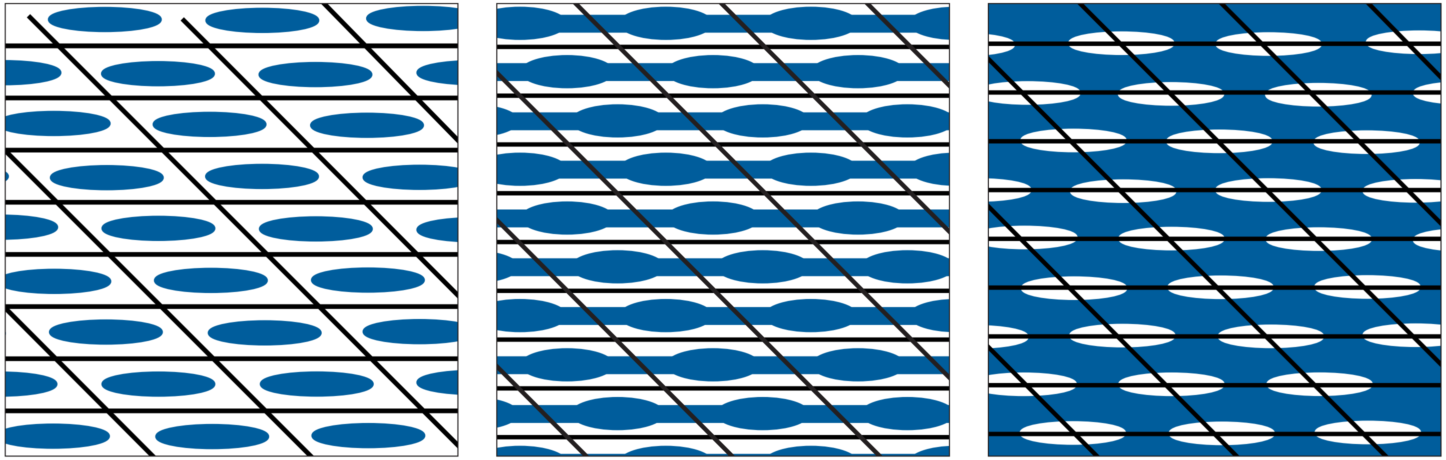


Figure 67: Megadot Plus in highlight, midtone and shadows.

4.9 Technologically Surpassed Screens

The screens described below have been removed from the sales program and replaced by new developments. They are still being supplied however for compatibility reasons and will therefore also be touched on in this book.
The general comments on frequency-modulated screens at the start of Chapter 4.6 also apply here.

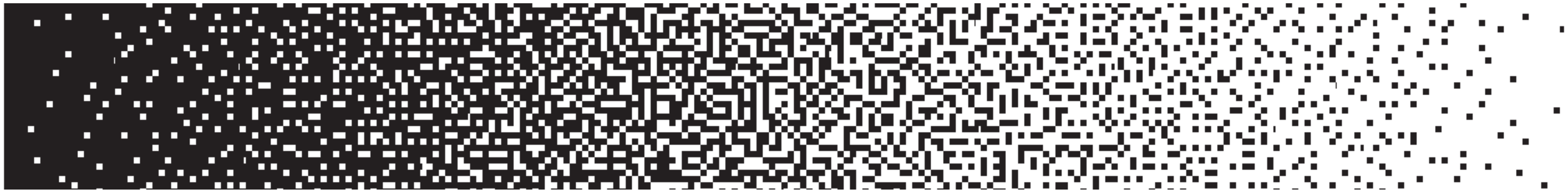
4.9.1 Diamond Screening

Diamond Screening was first replaced by Satin Screening and then by Prinect Stochastic Screening.
Diamond Screening is a first-generation FM screen. It has a particularly finely spaced structure made up of clusters measuring a minimum of 2 x 2 imagesetter pixels arranged in a quasi random pattern. Images would appear very grainy if the dots were actually distributed at random. Care was also taken to prevent the occurrence of repeating patterns.
The longer border line of the screen dots in Diamond Screening compared to newer FM screens causes a significantly greater dot gain in print. For this reason, process calibration is recommended.
As a general rule for this screen, the print conditions should be very carefully monitored and kept constant.

4.9.2 Satin Screening

Satin Screening was replaced by Prinect Stochastic Screening, a new development.
Satin Screening is a second-generation FM screen with a somewhat 'worm-like' structure. It is fundamentally different from the Diamond Screening method just described. In particular, the algorithms for generating the screens had been so significantly enhanced that smoothness in print was visibly improved and coarser clustering achieved.
The coarser clustering reduces the dot gain in print and therefore makes processing easier than with Diamond Screening.
With Satin Screening, the dot gain in print is greater than with conventional screens. For this reason, process calibration is recommended.
This screen is more stable in production than Diamond Screening. The print conditions must nonetheless be very carefully monitored and kept constant.

Figure 68: Diamond Screening (enlarged).



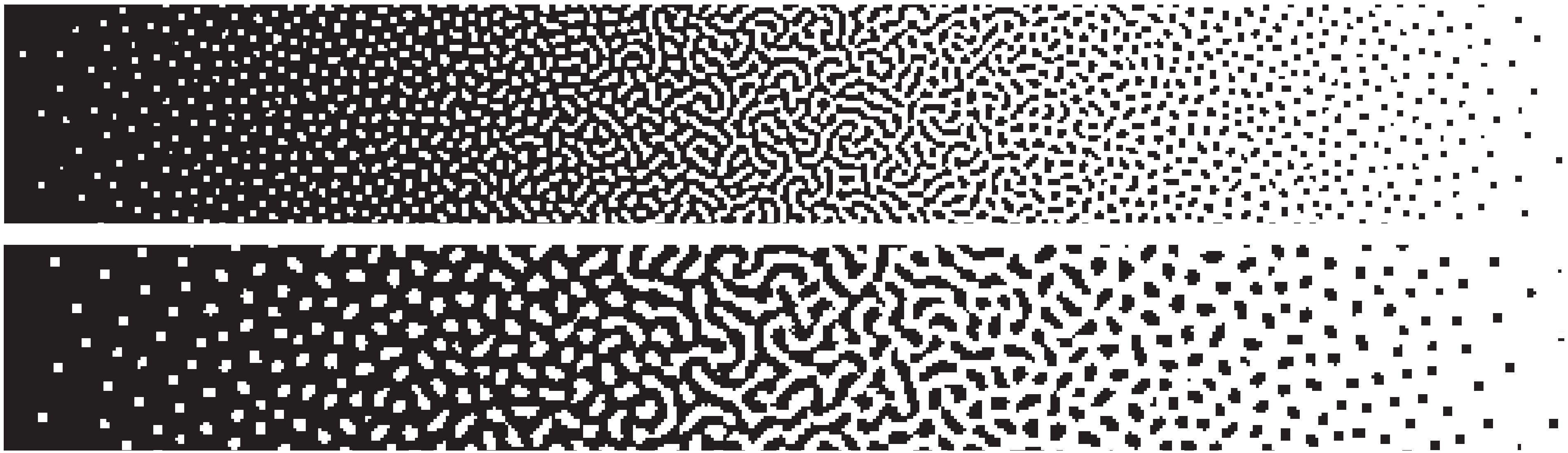
4.9.2.1 Satin fine

This screen begins in the highlight area with small dots mostly measuring 2 x 2 imagesetter pixels. These merge in the midtones to form fine ‘worm-like’ structures and small holes are once again generated in the shadows.
This finer screen is suitable for artwork and high-quality commercial printing. The Satin fine screen is also suited to flexographic and silk screen printing, as no moiré can occur with the silk screen.

4.9.2.2 Satin medium

This screen begins in the highlight area with small dots mostly measuring 3 x 3 imagesetter pixels. These merge in the midtones to form coarser ‘worm-like’ structures and small holes are once again generated in the shadows.
This screen dot is suitable for newspaper printing and work on uncoated paper.
The Satin medium screen is also suitable for flexographic and particularly silk screen printing, as no moiré can occur with the silk screen. The applications of the ‘fine’ and ‘medium’ Satin dot shapes overlap to some extent.

Figure 69: Enlarged vignettes with the Satin fine (top) and Satin medium (bottom, enlarged) screens.



5 Screen Settings in a PostScript Workflow

In the previous chapters, we explained the differences between PostScript screens, which were implemented by Adobe in the interpreter, and Heidelberg screens. Now we will take a look at how screens can be used in the prepress workflow. Every workflow is based on the interaction of a number of software components. As far as screening is concerned, the workflow begins in one of the popular page-design applications such as QuarkXPress® or InDesign® and ends in the RIP. The data exchange is based on standardized data formats, the specifications of which also define the possibilities for controlling screening in the RIP. The possibilities for the page description languages PostScript and PDF (Portable Document Format) and for the Job Definition Format (JDF) are explained below.

This chapter will first look at the main aspects of screening in the various standards, as well as how the broader functionality found with Heidelberg screening can be used within this scenario.

This information is intended to assist you when a screen does not image as expected.

Although workflows with PDF and JDF are being used increasingly in the prepress stage, we nonetheless recommend you do not skip the following chapters about PostScript. These chapters provide some fundamental information that is also relevant to the other workflows.

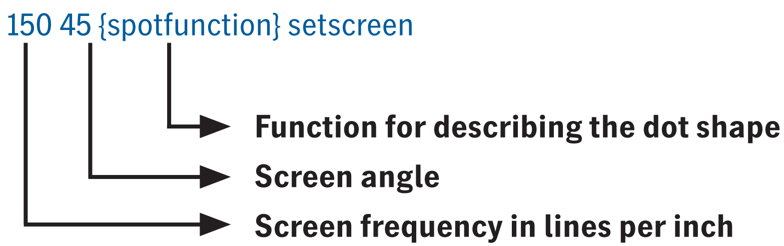


Figure 70: Example of the 'setscreen' operator in PostScript

5.1. Screening in the PostScript Workflow

PostScript is a page description language with programming capabilities. It enables the creation of graphic descriptions that are completely independent of the output system. In the prepress environment, however, device-specific additions are necessary that limit the reusability and exchange of PostScript files. Screening falls into this category.

5.1.1 History of the Development of PostScript Screening

When the first PostScript RIPs were developed in the 1980s, the development of screening technology had advanced so far that conventional screens could be very precisely approximated with the aid of supercells, and even irrational screens were possible with the appropriate hardware support. Nevertheless, the PostScript interpreter performed only single-cell screening. This meant there were only a few limited ways of generating screens. While it was possible to configure dot shape, screen rulings and screen angles very precisely through the 'setscreen' operator, the implementation resulted in some serious restrictions:

- The angles and screen rulings that were actually possible only allowed a very limited quality of color reproduction, and only a small number of RT screen combinations were possible.
- Depending on the screen frequency, resolution and calibration, far fewer than 256 tonal values were available in many cases. This resulted in clear instances of banding particularly with vignettes.

This situation led to Linotype and Hell, as licensees of Adobe RIP technology, integrating their own screening technologies into the Adobe PostScript Level 1 interpreter. These developments form the basis of today's Heidelberg screening solutions.
As well as the actual screen implementation, screen setups have also always been a key aspect. In many workflows, the PostScript code contains only insufficient or even contradictory data about the required screen. However, the RIP at the end of the prepress stage is expected to produce a sensible result despite the missing information.
PostScript Level 2 and PostScript 3 brought improvements to PostScript screening, in terms of both Adobe's standard implementation and the setup functionality. Part of PostScript Level 2, with additional improvements in PostScript Level 3, is the 'Accurate Screening' supercell technology where the possibilities for screen angles and screen frequencies can be compared to those of HQS. Nevertheless, HQS is still way up front in terms of the way it creates supercells and the high-quality smoothness and lack of structures.
Even in state-of-the-art PostScript Level 3, not every screen angle/screen frequency combination is possible, although approximations can be achieved that produce relatively good results. However, the real 'irrational angles' found in IS technology are still not supported by the original Adobe implementation.

5.1.2 PostScript Screen Setups

Various screen types, known as 'halftone types' are described in the PostScript specification. These screen types can be divided into two categories. On the one hand, there are the classic halftone types, in which screen rulings, angles and dot shapes are denoted mathematically. In the sections below, they will be called 'setscreens'. These screens are converted to threshold matrices in the RIP process.
Then there are screen types that are supplied directly as threshold matrices, where screen angles, frequency and dot shape are defined implicitly from the dimensions and content of one or two threshold matrices. FM screens without angles or frequencies can only be coded in this way. In the sections below, these will be referred to as 'threshold screens'.
Both categories have variations designed for a monochrome (separated) or a color (composite[25]) workflow. The setscreens can be set up in two different ways: One way is to use the 'setscreen' operator or the 'setcolorscreen' operator for composite PostScript. The other is to use a halftone dictionary. There is not much to choose between these alternatives. Halftone dictionaries have the advantage that they can also record specific additional information (see Chapter 5.4.4, 'Object-specific Screens'). Threshold screens can only be described using halftone dictionaries. Details on halftone dictionaries and halftone types can be found in the 'PostScript Language Reference' (ISBN 0-201-37922-8).
According to the PostScript specification, screens are device-specific. This means that you cannot expect to find all the different screens listed in the PostScript specification in one RIP. The screen parameter setups that a RIP actually supports are described in the product documentation. The control consoles of course also display this information.
Modern Heidelberg RIPs with software screening support not only Heidelberg screen systems but also PostScript halftone types. Older RIPs with hardware screening are not as flexible in this respect and can only support the halftone types to a certain extent.

5.1.3 Screen Setups in Printer Drivers and Applications

From the point of view of an application, a filmsetter or platesetter is simply one of many devices supported. In order not to have to deal with the device properties, many applications leave the generation of the PostScript code to a driver (LaserWriter, Adobe PS), but even the driver cannot know all the possible devices. How is the driver to tell whether setups for screens need to be included and what screens are supported? What's more, screen parameters in the PostScript definition are only partially suitable for user input or may not be suitable at all. With setscreens, two of the three parameters (screen ruling and screen angle) could be adopted directly from a user entry. The third parameter however – dot shape – is always based on a PostScript program which can be quite long. Simple designations for dot shapes such as 'elliptical' or 'round' must therefore be converted into PostScript code in some way. With threshold screens, there is no longer any direct relationship between the code at PostScript level and the description comprehensible to a user. Conversion from the user level to the parameter level is essential.

PostScript Printer Description files (PPDs) help to solve problems like these. These files contain the information about an output device needed by the driver in order to generate correct and complete PostScript. If the PPD contains alternatives, e. g. different paper formats, resolutions or screens, the user interface provided by the driver for selecting between these alternatives is not very user-friendly. Unfortunately, the PPD standard has weaknesses, particularly where screening is concerned (see Chapter 5.1.4).

The limited functionality of the drivers and PPDs can be enhanced with driver plug-ins[26]. Heidelberg offered the product 'Jobstream' for a time to handle this task. This plug-in lets the user perform a complete parameter setup of Heidelberg screens with the same ease as on a RIP. Now, however, a workflow with job tickets has become the preferred option, as described in Chapter 5.5.

Some professional prepress applications feature integrated support of screen setups. Applications must also tackle the subject of screen setups when they generate PostScript themselves without the support of the driver. Usually, there is a PPD-based selection to choose from, similar to that found in the driver, but it is also possible to define the screen angle and ruling for each color and select dot shapes. How these values are then converted for output depends on the product in question.

Fully integrated support for application-specific screens using the methods described is only found in specific applications (e. g. security printing).

5.1.4 PPD Screen Parameters

PostScript Printer Description (PPD) files are formalized text files that comply with the Adobe PPD specification. They are not part of the PostScript specification.

PPD files (or just PPDs) contain the specific information needed to generate PostScript for a specific output system such as a CtP platesetter. A PPD describes the properties of an output device or device family and how they can be activated using PostScript. A PPD-derived PostScript job is usually device-specific nowadays, and this can lead to errors when it is output to a different device.

PPDs are created by the manufacturer of the output device and generally are made freely available. In some cases, they are distributed with the operating systems. Adobe places PPDs for output devices equipped with the Adobe PostScript interpreter on the Internet. The latest PPD versions can usually be found through the manufacturer, however.

PPDs are often described as printer drivers. Strictly speaking, this term isn't correct since drivers and applications only take information from the PPDs about the specific options available in PostScript output systems and how to activate certain functions. However PPDs, unlike printer drivers, do not generate code which is the most basic task of a driver. Some examples of printer drivers are the Apple® LaserWriter or Adobe PS for the Macintosh® and the various Windows versions.

A PPD has invariable parameters and parameter lists. The invariable parameters can be, for example, the PostScript version supported by the PPD, the name of the manufacturer and the model number of the output device. The parameter lists offer several alternatives. The best example here is the list of output formats. The user can choose from several standard formats and, if it seems appropriate, a user-defined one.

The PPD specification does not have a screen system concept and, as a result, cannot support a full description of Heidelberg screens. The complex interaction of screen system, screen rulings, resolutions and dot shapes cannot be portrayed. The rules on how items are to be displayed in the user interface are sometimes missing as well. The result of this has been that some applications have a very confusing way of displaying particular items. Consequently, the PPD restrictions do not allow applications and drivers to define a full, job-specific screen setup for the output run.

This is why Heidelberg developed a supplementary concept, as described in Chapter 5.2. In terms of screening, the PPD concept has been kept very simple. The PPDs do not contain the angles of the different screen systems, but just the standard angles of 15°, 75°, 0° and 45° for CMYK. A list of the most common screen rulings for the most frequently used imagesetter resolution is included as well. The resolution itself cannot be selected in the PPD, and portraying the interrelation between screen frequencies and resolutions cannot be implemented with PPDs.

5.1.5 Summary of the Weaknesses in the Standard PostScript Workflow

On the whole, it can be said that applications, drivers and PPDs do not support screening in the way they should, and the manufacturers of prepress applications will always come up with good reasons why, the most crucial of these being the multitude of different devices available. The user is faced with a number of drawbacks because of this, the most important of which are listed below:

- Customized screen setups require extreme accuracy. Entering numbers with many digits for each color is full of pitfalls and typos can prove to be expensive.
- Customized screen setups can result in unwelcome surprises in the overprint. Not being familiar with a screening technology or not knowing how the RIP deals with the inputs can produce bad overprints.
- PPDs are not capable of describing the complex potentials and relations screens have in a prepress workflow.
- It is practically impossible for an application manufacturer to offer optimal screens for all the different output devices that exist on the market today. However, using a screen that is not optimal involves the risk of artifacts appearing in print. For that reason, using an application's screen should be confined to monochrome ornamental screens with coarse resolution. Screens are device-specific, and Heidelberg has invested a lot of effort into optimizing screen systems and dot shapes so that its customers can have top-of-the-scale output quality.
- The editorial or design department and production are separate units in many firms. The responsibility for quality and, consequently, for screens usually lies with production. Therefore, giving production full control over screens without involving the editorial department is something that should be considered.

For workflow quality and reliability, we recommend working only with Heidelberg screens and using the correct PPDs to define their setup. If the wrong PPDs are used, you might even end up with a PostScript job that has no screen parameters at all. If this job happens to be separated as well, an output with suitable color screens is often impossible (see Chapters 5.2.1.1, Screen Angles as Color Aliases, and 5.2.1.2, Filtering Comments).

5.2 Heidelberg's Concept for Screen Setups in a PostScript Workflow

The many restrictions in all of the components described above led to the development of a Heidelberg concept for screen setups. This concept works on the principle of only a minimum number of standard-based screen setups yet allows flexible use of Heidelberg screening. The user can benefit from this concept as follows:

- Heidelberg screen systems can be used despite the standard PostScript language restrictions. Every PostScript file that fulfills the minimum requirements for screen parameters can be imaged with Heidelberg screens. Even non-standard PostScript can be processed in most cases.
- The user can select parameter sets from lists in the output device's user interface. The screen system concept does away with the need to enter figures for the single color separations. Specialized screen know-how is not required, and the chance of producing faulty overprints because of typing errors is slim.
- The user can decide for his/her own business whether screens will be set up directly during the job in the application or in the driver or RIP. The editorial and production departments may be either separate or integrated.

In order to image a PostScript job with Heidelberg screens, a RIP must have the following information:

- Color separation
- Screen system
- Dot shape
- Screen ruling
- Imagesetter resolution

The chapters that follow explain how the RIP obtains this information, concluding with the special case of setup via Jobstream.

5.2.1 Determining the Colors

The angles of a screen system are assigned to the separations of a PostScript job by color. In order to determine the color of a separation, a PostScript job must fulfill certain minimum requirements. A distinction is drawn here between composite and separated PostScript.

There are no minimum requirements for a composite PostScript. Information about the color separations is created automatically during the separation in the RIP.

Separated PostScript is a different matter. The information about the color separations is not contained in the actual PostScript code. The RIP regards a separation in a separated job as a black-and-white page and cannot assign it to an angle in the screen system without receiving more information first. The information it needs can be provided in two different ways:

- The screen angle acts as an alias for the color.
- The PostScript data color comments are evaluated.

5.2.1.1 Screen Angles as Color Aliases

Angles generated from the PostScript code are evaluated in a special way in Heidelberg screening. Invariable angle values serve as an alias for the color of a separation and not as parameters for screening. The color is a stepping stone in the allocation of an angle in the screen system. The diagram opposite shows which angle ranges in PostScript are mapped onto which colors. To ensure this mechanism functions correctly, the angle values defined by the Heidelberg PPD must of course be contained in the PostScript code.

The advantage of this approach is that the user doesn't have to think about screening when printing from the application but can always work with the same settings. The generated PostScript code can be output later with any screen system.

Heidelberg PPDs therefore deliberately contain only the angles 0°, 15°, 45° and 75°, although no screen system has exactly these angle combinations. The angles in the PostScript code are allocated to the angles in the screen system using a filter program[27] in the RIP, taking into account the screen system selected.

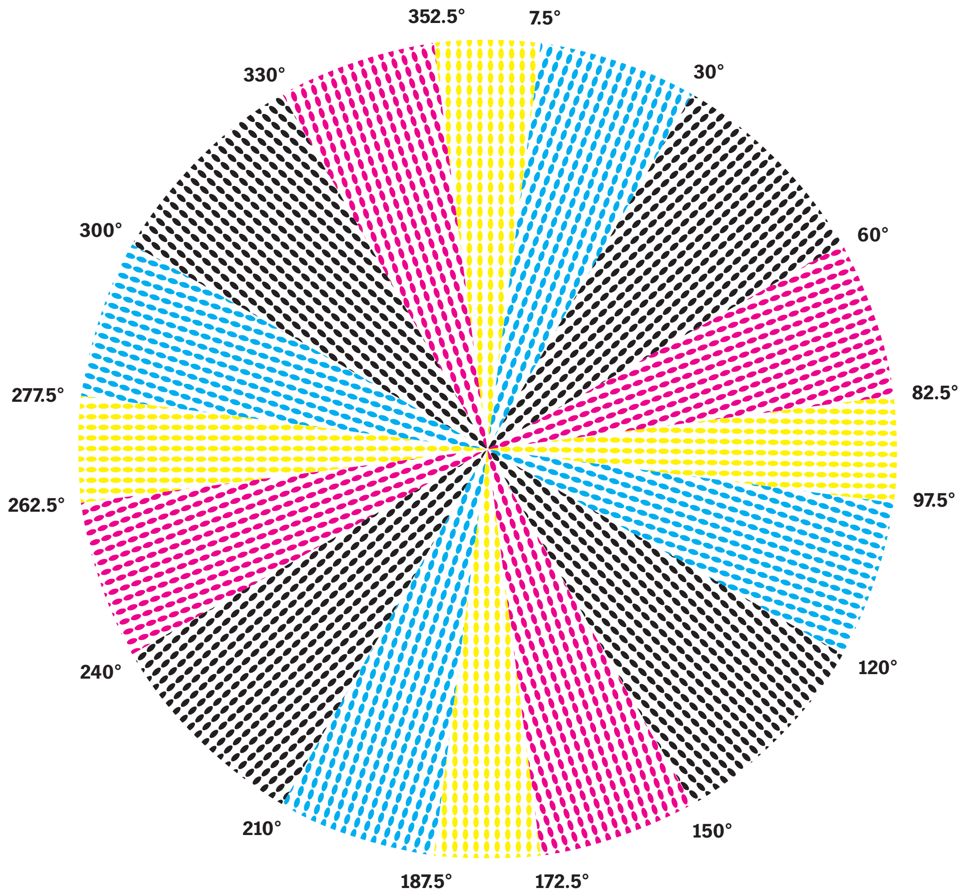


Figure 71: Angle ranges of the individual color separations.

5.2.1.2 Filtering Comments

In separated PostScript, Heidelberg screens can be controlled by evaluating not only the setscreen PostScript commands as described above but also the PostScript comments.

Adobe defined Document Structuring Conventions (DSC comments) as a supplement to the PostScript specification. These DSC comments should not be confused with the DCS (Desktop Color Separation) data format[28]!

As far as PostScript specification is concerned, these comments are not an obligatory part of a PostScript job, but they have turned out to be pretty reliable and are even essential for some functions (e. g. OPI). Customer-specific comments are also possible with DSC – an option that is frequently used. Certain color comments, including customer-specific ones, are evaluated for screening. Once the color is noted, a color separation can be clearly allocated an angle of the active screen system. The following example shows the DSC comments in a PostScript job. The actual PostScript code is contained in the lines marked with ...

```
%!PS-Adobe-3.0
%%Title: ...
%%Creator: PScript5.dll Version
5.2.2
%%CreationDate: ...
%%For: ...
%%BoundingBox: (atend)
%%Pages: (atend)
%%Orientation: Portrait
%%PageOrder: Special
%%DocumentNeededResources:
(atend)
%%DocumentSuppliedResources:
(atend)
%%DocumentData: Clean7Bit
%%TargetDevice: ...
%%LanguageLevel: 3
%%EndComments
%----------------------------
%%BeginDefaults
%%PageBoundingBox: 0 0 595
842
%%ViewingOrientation: 1 0 0 1
%%EndDefaults
%----------------------------
%%BeginProlog
%%BeginResource: ...
...
%%EndResource
...
%%EndProlog
%----------------------------
%%BeginSetup
...
%%EndSetup
```

```
%%Page: 1 1
%%PageBoundingBox: 0 0 595 842
%%EndPageComments
%----------------------------
%%BeginPageSetup
...
%%EndPageSetup
%----------------------------
%%BeginDocument: ...
%!PS-Adobe-3.0
%%Title: ...
%%Version: 1 4
%%Creator: ...
%%CreationDate: ...
%%For: ...
%%DocumentData: Clean7Bit
%%LanguageLevel: 3
%%BoundingBox: 0 0 612 792
%%HiResBoundingBox: 0.0 0.0
612.0 792.0
%%Pages: (atend)
%%DocumentProcessColors:
(atend)
%%DocumentCustomColors:
%%+ (PANTONE 2603 C)
%%CMYKCustomColor:
%%+ 0.690 1.0 0.0 0.0196 (PAN-
TONE 2603 C)
%%DocumentSuppliedResources:
%%+ procset ...
%%EndComments
%----------------------------
%%BeginDefaults
...
%%EndDefaults
```

```
%%PlateColor: Cyan
...
%%BeginDocument:...
...
%%EndDocument
...
%%PageTrailer
%============================
%%Page: 2 2
...
%%PlateColor: Magenta
...
%%EndDocument
...
%%PageTrailer
%============================
%%Page: 3 3
...
%%BeginDocument:...
...
%%PlateColor: Yellow
...
%%EndDocument
...
%%PageTrailer
%============================
%%Page: 4 4
...
%%BeginDocument:...
...
%%PlateColor: Black
...
%%EndDocument
...
```

Figure 72: Example of the DSC comments in a PostScript job. The actual PostScript code is contained in the lines marked with ...

5.2.2 Assigning Colors to Angles

Each screen system has a definition stating which angle belongs to which color. This can be regarded as the default setting. A dialog in the user interface of the RIPs lets the user assign the color separations to other angles as well. However, only the four angles that are in the screen system can be used. Only these angles are available for spot colors as well. Each spot color can be assigned one of the four angles with the help of filter comments (see Chapter 5.2.1.2, Filtering Comments).
With PostScript filtering for a separated output, the set allocation of colors and angles only works when the job in question has the color/angle allocation defined in the PPD. If not, angles could be switched unintentionally.

5.3 Selecting Screen Parameters in Heidelberg Products

Parameters for Heidelberg screens are selected in special user interfaces. The basic settings can be found in similar form in all Heidelberg RIPs, even though the graphic design and one or two minor details might be different. The parameters only have to be selected, making any typing in of figures unnecessary.
There are numerous dependencies between the various screen parameters. When one parameter is changed, the choices you have for another parameter can also change. This interaction is integrated in the user interface, and only available parameter combinations are displayed. Because of this interaction between the different parameters, you should always select parameters in the order given in the user interface, from top to bottom and from left to right. The screen system should always be selected first.

5.3.1 Selecting Screen Systems

All the screen systems in a RIP can be viewed in a pop-up menu in the user interface. One of these systems can then be selected from the list. Using several Heidelberg screen systems within one job is not supported within the framework of the PostScript workflow, although it can be done with object-specific screening (see Chapter 5.4.4, Object-specific Screening).
One of the items in the pop-up menu disables Heidelberg screening and enables PostScript screening. The name of this menu item varies depending on the product. New products use the term ‘Document controlled screening’. When this system is enabled, all the RIPs can support at least PostScript screening with setscreen setups. The generated screens are then based on original Adobe screening or, in the case of hardware RIPs, on a compatible Heidelberg implementation.
PostScript threshold setups are supported in some of the newer software RIPs. Which screen systems are available in a certain product depends on three factors:

1. The product itself
2. The output device
3. The availability of an option.

In the case of the first item, it is important whether the RIP used has software or hardware screening. Almost all Delta Technology[29] products have hardware screening, so it is technically not possible to generate IS screens on HQS hardware and vice versa.
The output device mainly influences screening through the resolutions that it offers. The screen frequencies that can actually be generated depend on this factor. Certain screen frequencies are only available with certain resolutions, their combination usually depending on the output device you use.
The third item refers to screens that aren’t included in the standard scope of delivery, but which can be purchased separately, for example, Prinect Hybrid Screening and Prinect Stochastic Screening.
Some of the names of the screen systems are registered trademarks. They therefore remain the same whatever the language of the user interface.

5.3.2 Selecting Screen Dots

The user has a choice of dot shapes in almost all screen systems. The dot selected in the Heidelberg screen's dialog is not changed by the PostScript job's dot shape.

5.3.3 Selecting Resolutions and Screen Rulings

There is a close connection between resolution and screen ruling (see Chapters 6.4 and 7.4).
Not every screen ruling is available for every resolution. The selection dialogs of these two parameters ensures that only available combinations can be selected.
The values the user can select also depend on the screen system used. A nominal value is selected for the screen frequency.
There are generally slight differences between the nominal value and the actual screen ruling. This is something that cannot be avoided if the user prefers to use just one value for all the separations, leaving aside the many different screen frequencies to choose from in the screen systems (see Chapter 4.1.1 AM Screen Systems).
Another reason for the difference in values is that the quality-based correlation between resolution and screen ruling usually results in fraction numbers for the actual screen frequency and these are not at all suitable for user interfaces. The actual values are documented in the 'Screen Frequencies' user guide. In critical cases, the user should take note of the values available in order to avoid any unwelcome surprises.
The screen frequency set in the user interface can be set to fixed or overwrite. The job either uses the screen ruling from the setscreen setup or ignores it, depending on what is set. The values from this job are then rounded off to the next value in the screen system. In this case, all color separations must have the same value.
The user should enter these settings carefully because the RIP may round off the values differently if variations occur.

5.3.4 Jobstream

Jobstream is a printer driver plug-in that was developed for Delta Technology. It enables full setup of a Heidelberg screen using proprietary enhancements in PostScript. This means that a code can be created directly when PostScript is generated, eliminating the need for any further setups.
The JDF job ticket workflow now offers comparable functionality, so further development of Jobstream has ceased.

5.4 Screening in the PDF Workflow

5.4.1 History of the Development of PDF

Portable Document Format (PDF) is a page description language. PDF has been used in the prepress environment as an alternative to PostScript since the second half of the 1990s. Acceptance was slow at first, but PDF is increasingly gaining in popularity and is set to replace PostScript as the preferred prepress format in the medium term.
Like PostScript, PDF was also defined by Adobe. The two formats are clearly related, with conversions possible from one to the other. Conversion from PostScript to PDF is performed by Adobe 'Distiller' or 'Normalizer' software. PDF Library is used for converting PDF to PostScript. Normalizer and PDF Library are not freely available. They can be obtained by Adobe OEM customers for integration into their systems.
Since the first specification in the mid-1990s, the functionality of PDF has developed at a colossal rate. With every new version of the 'Acrobat' application, a new version of the PDF specification is released with new functions. However, these functions are often not relevant for prepress use. For prepress application, various subsets of PDF such as PDF/X and PDF/A have been internationally standardized.
The key differences from PostScript are as follows (not an exhaustive list):

- Greater reliability due to absence of programming capability
- Device-independent
- Incorporates all resources (e. g. fonts)
- Possible to access individual pages of a document.

5.4.2 Screen Setups in PDF

When you analyze the screening possibilities in PDF, the format's affinity with PostScript soon becomes apparent. The halftone dictionaries from PostScript are found in almost exactly the same form and all the options described in the chapter on PostScript screening are also available for PDF.

5.4.3 Screen Setups for PDF in Printer Drivers and Applications

PDF files are generated either indirectly via PostScript with subsequent conversion to PDF or directly from applications.

With the PostScript method, all explanations from the previous chapters apply. Device-dependent PostScript generated using the PostScript driver and PPD is used to create device-dependent PDF. This dependency somewhat contradicts one of the basic premises of PDF, but is minimized by the Heidelberg PPDs.

When PDF is written directly from applications, it is usually not possible to perform device-specific setups. In that case, this information has to be added later at the RIP output stage.

5.4.4 Object-specific Screening

With the help of screen setups in PostScript and PDF, every graphic object can in principle be allocated its own screen (e. g. images, text, graphics). There are, however, only very few applications that can provide the support required to actually do this. The screen setups are then restricted to the options available within the PostScript/PDF framework. It is not possible to select Heidelberg screen systems.

Heidelberg has therefore developed an Acrobat plug-in that can be used to allocate different Heidelberg screens to the graphic objects of a PDF. It does this via an entry created by Adobe in the halftone dictionary especially for this and similar purposes. The content of the entry is manufacturer-specific. The screens are set up by the Heidelberg RIP, when it has been enabled to do this.

With object-specific screening, users typically want to use a combination of FM screens for images and AM screens for all other objects. Combinations like this may be problematic to print, as AM and FM screens respond differently to overinking or underinking[30].

5.5 Screening in the JDF Workflow

5.5.1 The Origins of JDF

The subject of device-independence has been touched on a number of times in the previous chapters. Modern workflows aspire towards device-independence because of its clear advantages when it comes to exchanging and re-using documents. The question is, however, how do you set parameters for device-specific features when the actual page description is not supposed to contain these any more?

To solve this problem, Adobe invented the Portable Job Ticket Format 'PJTF'. This is a special PDF data format used to describe jobs for the RIP. It contains all the information for output, e.g. screen parameters, calibration information and layout. However, as the specification is not comprehensive enough to cover all eventualities, proprietary enhancements have been developed by all manufacturers and these are not interchangeable.

The limitations in PJTF led to a cross-manufacturer initiative to define a standard format for the manufacture of print products, leading to the development of the Job Definition Format (JDF).

Unlike PostScript and PDF, the content of JDF and the software that supports it were developed not by a single company, but by a committee (CIP4). This resulted in a specification that covers practically every conceivable workflow variant and extends from costing to finishing. Although the level of complexity is high, it is also optional, so the desired interchangeability of data is no longer guaranteed. For individual workflow stages, therefore, subsets were defined as a minimum standard for data exchange. This minimum standard is defined by the 'Interoperability Conformance Specifications' (ICS).

5.5.2 Screen Setups in the JDF Workflow

The possibilities for screen setups in JDF are relatively extensive compared to PostScript or PDF. Only the basic principles and key aspects will be looked at here. The relevant documentation must be consulted to establish what options are available with a particular product.
JDF is a hierarchical format that can nonetheless also describe networks of process steps. A job is therefore structured in both a product-related way and in terms of process steps.

- The top level is the job.
- The job consists of sheets.
- The sheet has a recto and a verso side.
- Each recto and verso side consists of placed objects (e.g. pages or printing marks).

Firstly, rough parameters for screening can be set in JDF both from the customer's point of view and from a costing perspective, specifying typically the type of screen (AM, FM or hybrid) and the screen frequency. No provision is made for a breakdown according to object type.

In the description of the technical screening process, screens can be set up at every level. There can be only one screen setup at top level, but different setups may also be present at lower levels. In this case, the setup of the lowest level is always used.
Within the screen setup, the validity may be restricted to graphic elements of a particular type. A distinction is drawn between the following types: Image, text, vector graphic (drawing) and vignette. This restriction can extend to all levels. It is therefore comparatively easy to output all images in a particular job with a different screen.
The process becomes more complicated when a different screen is to be used only for the images on particular pages, because in that case a corresponding entry for these pages must be present in the JDF. In extreme cases, if only one image out of several on a particular page is to be output differently, this is not possible with JDF alone. The JDF then contains only the instruction to evaluate the screening of the PDF for the affected placed object.
In this case, Heidelberg uses either the object-specific screening described above or standard PDF screening.
It is possible to allocate screens automatically to a JDF job if all graphic types within a job are to be screened identically. In the event of exceptions, the job must be interactively processed either in JDF or PDF depending on the situation. In extreme cases, object-specific screening in PDF offers the greatest flexibility, enabling individual objects to be accessed. If this is applied to all objects within a job, the same effects can be achieved as with JDF.

5.6 Summary

The wide range of screen-setup options catered for by the combination of JDF and PDF covers not only everyday requirements but also many special cases. As the majority of applications do not require the special cases, however, many RIP products support these cases only partially or not at all. The reasoning behind this is that, as the complexity of the screen setups increases, so does the complexity of the user interface and the operator know-how required. For this reason, the user interface for screen setups in a RIP product and therefore also the options for special setups are always tailored to the intended use.
With JDF and PDF too, screens remain device- and manufacturer-dependent. It remains problematic to exchange JDF files or PDF data with object screening between products from different manufacturers. Reliably predictable screening results on a Heidelberg RIP are only produced if the screens are also set up using a Heidelberg product.

6 Laser Imagesetters

The vast majority of all print originals are created nowadays with platesetters (Computer to Plate[31]). This chapter will describe the structure and principal properties of various types of imagesetters.
Certain imagesetter properties influence what is possible in screening. These aspects will be examined below.
There are two key technologies for designing CtP imagesetters:
- External drum imagesetters
- Internal drum imagesetters

All laser imagesetters work on the same principle, which is that one or more laser beams "write" image information line by line, in parallel, onto photosensitive material.
The laser is switched on in those areas where the printing plate is to be exposed; otherwise, it remains switched off. The laser beam is switched on and off digitally in a precisely defined cycle. The individual laser spots that can be switched on and off are known as pixels, derived from 'picture element'. Each screen dot is made up of a certain number of imagesetter pixels. This principle lies behind the way a screen is constructed into the pixel matrix of an imagesetter.
In practice, both the line spacing and the pixel frequency normally lie between 7.5 and 20 µ.
Unlike the electron beam in TV tubes, laser beams cannot be deflected by electromagnetic fields. Light can be deflected over large distances only by using mechanical means. Added to this is the fact that the deflection must be bi-directional – rapidly in the direction of the laser line, and relatively slowly from laser line to laser line.
Many publications use the terms image line, scan or fast scan instead of 'laser line'. The direction perpendicular to this is the feed or slow scan.
The various types of imagesetter differ mainly in terms of the principle used for generating image lines and feed.

6.1 External Drum Imagesetters

External drum imagesetters have built up an impressive record for high-quality film work in the repro industry over many years. This method has now also become established for imaging printing plates. The printing plate awaiting exposure is mounted on the outside of the drum on this type of imagesetter. Exposure takes place along the length of the rotating drum using a laser head (see Figure 73), which in turn is moved along the drum with great precision by means of a spindle. The image lines are written by the rotation of the drum, while the slow movement of the laser head effects the feed. This type of construction requires a very stable design because of the relatively large moving masses and the imbalance created by the material clamped to the drum. Fixing the material to the drum is not an easy matter. To keep the centrifugal force and imbalance at an acceptable level, the rpm count must be kept relatively low. To achieve acceptable imaging times, several laser beams have to be used at the same time. These beams can be arranged so that different areas of the drum are exposed at the same time, or so that a "light rake" exposes image lines lying directly adjacent to each other.
The principle of the light rake is a well-known one. Different designs can be used for generating the parallel laser beams. The most popular one is the splitting of a single laser beam into a "light rake" comprising parallel light beams which are then modulated individually. An acousto-optical modulator (AOM) is used for this purpose. Lasers, beam splitter and AOM are all housed in a laser head.
Nowadays, a laser diode array or an array of modulators illuminated by laser diodes is used. This design allows very short optical pathways and particularly straightforward generation of high light output, allowing for the imaging of thermal printing plates, the industry's most popular plates.
To increase imaging speed even further, multiple adjacent optical heads can also be used to image a printing plate.

Regardless of the design of the laser head, there are two properties that can influence the quality of the screen:

1. The individual beams in a light rake must have the same light intensity.
2. The spacing between them must be exactly the same.

If the settings are not correct, both effects can cause a periodic 'light rake stripe' which can interfere with the screen. These interferences can be factored into the screening process and minimized (see sections 6.4 and 6.5). The Suprasetter® platesetter from Heidelberg is an external drum imagesetter with a laser diode array.

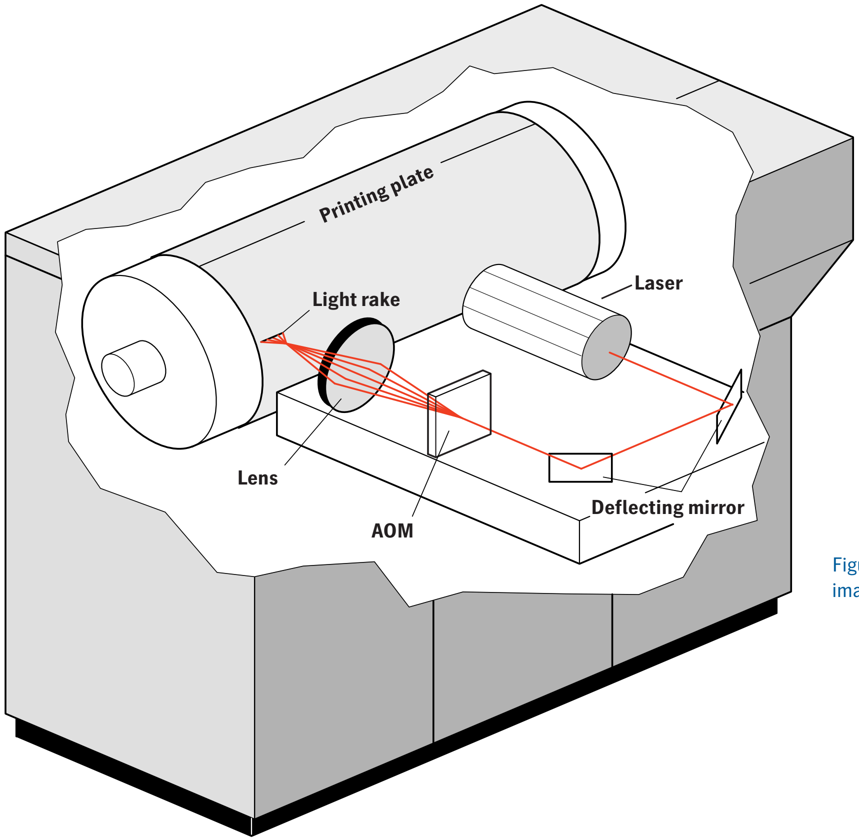


Figure 73: Schematic diagram of an external drum imagesetter with AOM.

6.2 Internal Drum Imagesetters

With internal drum imagesetters, the material to be exposed is held in position inside a partially open hollow cylinder. The laser and a deflection unit are then moved along its exact center. The laser beam is deflected via a fast-rotating prism and in this way an image line is written. The image lines and the feed are effected by moving the optical system. The material is not moved during the exposure process.
The rotating deflection unit is a relatively small component and can rotate at high speed. This means that production can be very quick using a single laser beam. The optical system as a whole is significantly simpler to put into effect.
Although the optical pathways are considerably longer than on external drum imagesetters, on the whole, it is easier to buffer vibration as the mass being moved is much smaller.
This type of imagesetter enables maximum quality at very high speeds and at a moderate price.
The Prosetter® platesetter from Heidelberg is an internal drum imagesetter with a UV laser.

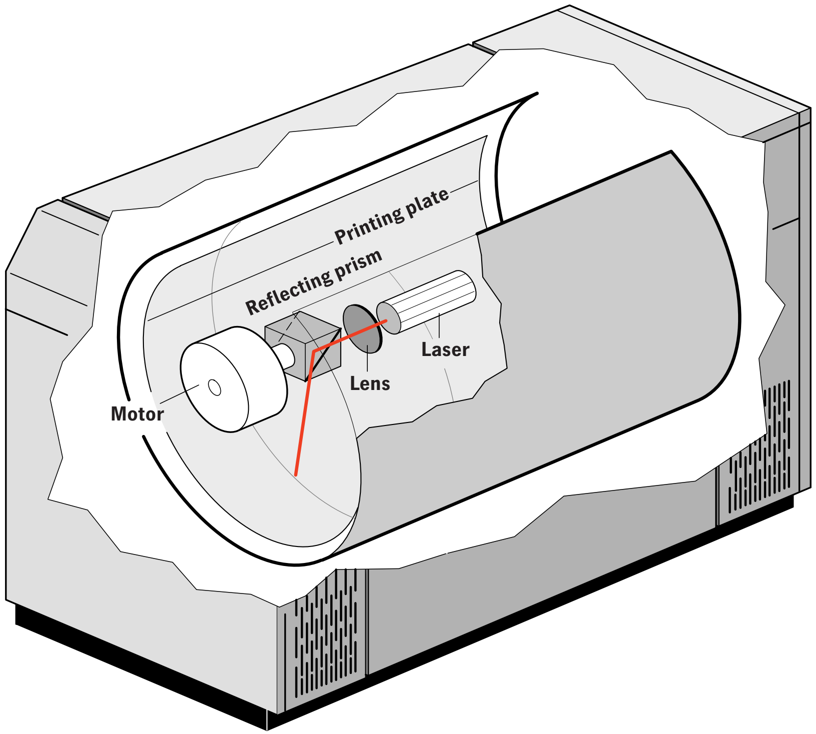


Figure 74: Schematic diagram of an internal drum imagesetter.

6.3 Resolution and Addressability

Laser imagesetters feature quite a number of resolutions which are usually quantified in terms of dots per inch (dpi) or lines per centimeter (l/cm). This value is often misinterpreted, since it doesn't describe the actual resolution, but rather the spacing between two image lines. A better term for this would be addressability. The imagesetter's resolution can be determined from the size of the laser spot ('spot size'). In ideal situations, this should be around 20 % larger than the addressability. This value is the best possible compromise between even exposure and maximum resolution.
Example: An imagesetter with an addressability of 2540 dpi (1000 l/cm) has a laser line spacing of 10 μ. The laser spot should therefore have a diameter of 12 μ. Because the intensity of the laser beam decreases towards the edge, even exposure is achieved through the nominal overlap of 2 μ. Individual laser lines without neighbors will be a fairly precise 10 μ wide. This of course only works if the intensity of the laser has been set correctly for the material that is used.

6.4 Light Rakes and Screen Dots

Light rakes are a typical feature of external drum imagesetters. The usual number of laser lines is between 8 and 250. The interplay with the screen period can result in interference which is mostly perceived as stripes running parallel to the image lines. Screens at 0° and 45° are particularly susceptible to this phenomenon.
At these angles, therefore, the screen dots are best made up of integral multiples of the light rake.
Example: A screen of 150 lpi (60 l/cm) at 2540 dpi (1000 l/cm) would have to be made up of 16.67 laser lines. On an imagesetter with 8 laser beams, it would actually consist of 16 lines, giving an exposure result of 158.75 lpi (62.5 l/cm). This rule of using integers is, wherever possible, also applied on internal drum imagesetters using just one beam, since otherwise the screen itself may contain interferential structures.
This limits the screen frequencies that can be achieved at specific levels of addressability.
There are also specific, preferred combinations of 0° and 45° angles for color reproduction. There are no pairs of equal 0° and 45° screen rulings where the screen meshes of both angles are made up of a whole number of lines. For this reason, the 0° angle often has a different screen frequency.

6.5 Imagesetter Adjustment

Calibrating the imagesetter to the specific material and processor is crucial for optimizing the optical system and minimizing the effects of the light rake. Depending on the type of imagesetter used, the prescribed procedures for the light value, focus etc. have to be performed carefully and repeated at regular intervals. A poorly calibrated imagesetter cannot give you good quality. The same goes for a poorly maintained processor.
Every printing plate requires a certain quantity of light to ensure reliable imaging and stability. Any non-linearity should be taken into account and compensated by linearization.

6.6 Linearization

The actual dot percentage achieved on the plate depends on the imagesetter, the material and the developing conditions. The dot percentage deviations of printing plates at 50 % nominal density vary depending on the type. With the correct method of working, even this deviation should be corrected by linearization.
In order to perform linearization, a step wedge[32] must be exposed, developed and calibrated using the appropriate tonal values. These measurements are entered into a software application (e.g. the Heidelberg Calibration Manager). The program then calculates the corrections so that the exposure results match straight away.
The Calibration Manager from Heidelberg stores the data in a database. Information about the validity range for linearizations is also kept on file, so that this work does not need to be repeated from scratch for each screen combination or screen frequency.
Measuring the dot percentage on a plate is a technical challenge that is being mastered with increasing success by the measuring instruments on the market (see Chapter 7.1 Printing Plates).
Linearizing printing plates is therefore recommended for the time being.

7 Screens in Print

Screening is an integral part of the overall print production process. It therefore makes sense for those in the business of print products to concern themselves with the other stages of the process, in particular print processes. The processing stages following creation of the printing plates or color separation films involve a few other aspects that need to be taken into consideration when these are first being created. Some of these stages no longer apply now that direct imaging is commonplace.
This is a very broad area, and it is not possible to examine all aspects of printing within the confines of this publication. However, the next few pages will list a few of the main ones.

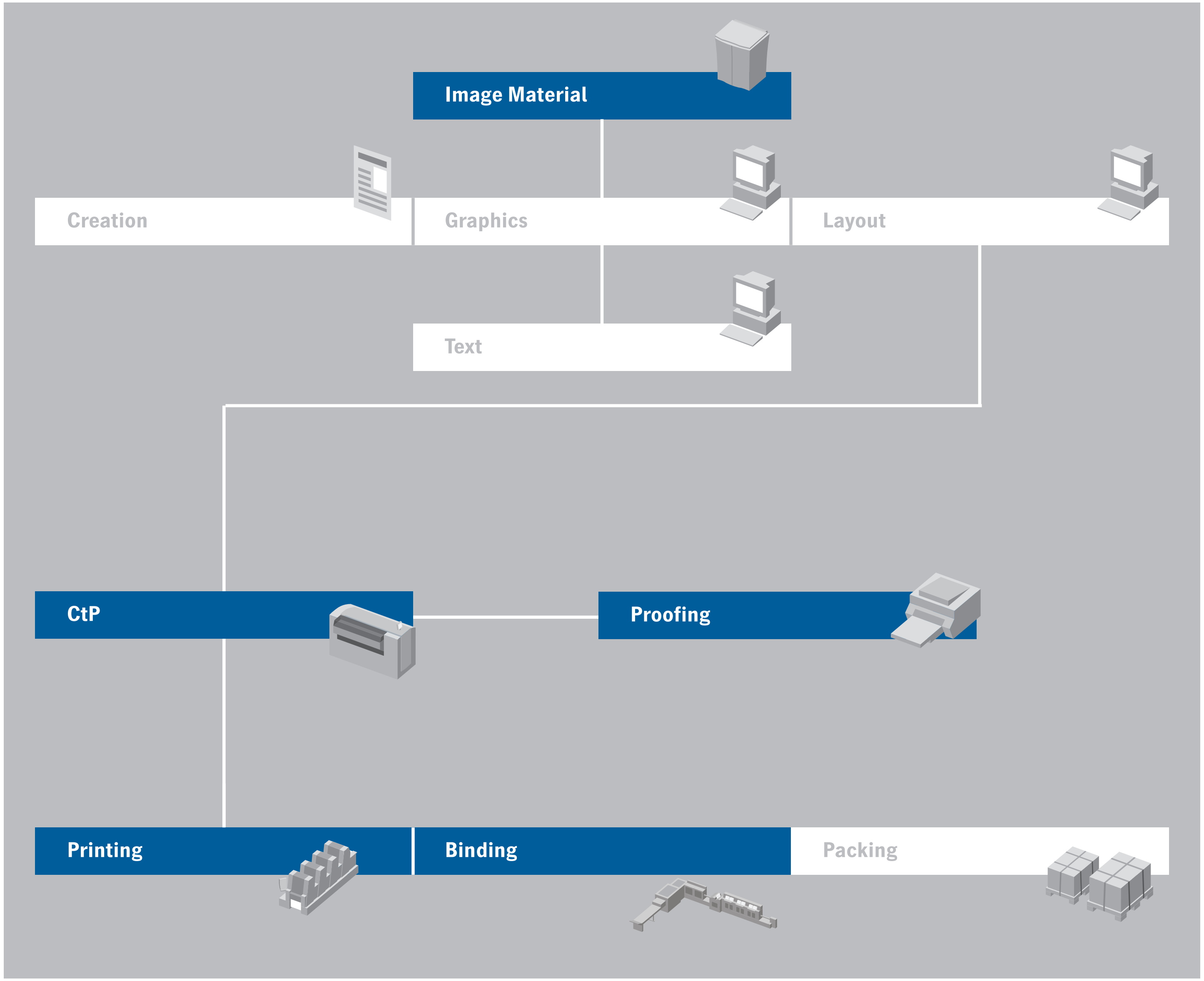
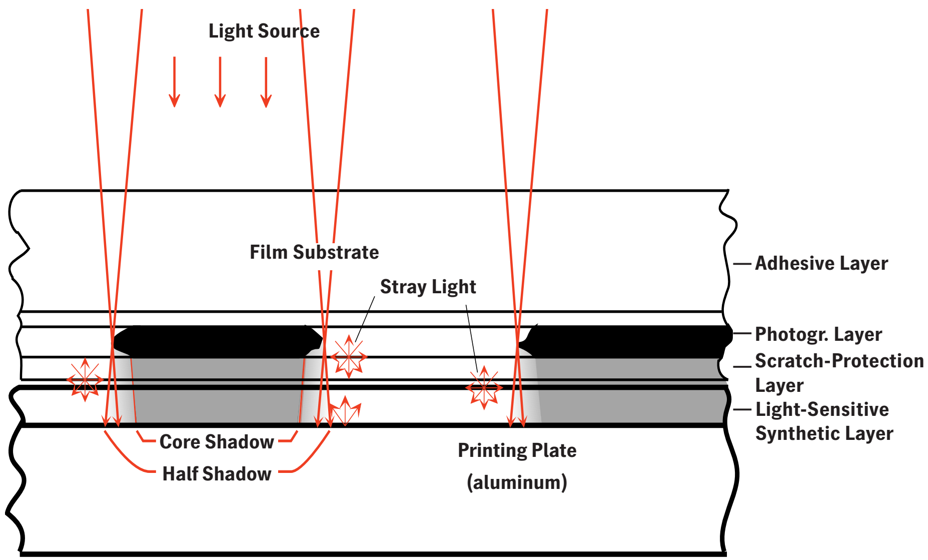


Figure 75: Printing production process.

7.1 Printing Plates

A printing plate normally consists of an aluminum substrate with a light-sensitive synthetic layer. At the oleophilic, i. e. oil-friendly, synthetic layer adheres the oily ink, while the hydrophilic, i. e. water-friendly, aluminum substrate is moistened in the press before each new print so that it cannot adhere any ink.
Printing plates can be imaged in a number of different ways. Currently, the two most common methods are exposure with violet light at approximately 400 nm and exposure with infrared light at approximately 830 nm. High-sensitive sliver halide-based printing plates are used for exposure with violet light. These plates are developed photo-chemically. Photopolymer[33]-based printing plates are much less sensitive. Exposure with violet light cross-links monomer chains so that the exposed sections survive the subsequent development process. The sections not exposed are washed away by an alkaline solution.
Far higher energy levels are required to image thermal printing plates.
The somewhat misleading names of printing plates refer to the type of film for which they are intended. Positive printing plates are intended for positive films and negative printing plates for negative films.
Exposing negative printing plates to heat causes primary cross-linking in the plate's polymer coating, which is then fixed in the developer by means of thermal processes. The unexposed areas can be washed away, which means that it is the exposed sections of the printing plate that print.
With positive printing plates, on the other hand, chemical bonds in the coating are broken down by heat. The exposed areas are washed away in the subsequent development process, which means that it is the unexposed sections of the printing plate that print.
The main advantage of thermal printing plates is the 'digital' way in which they work. An imagesetter pixel is only created if a heat threshold is exceeded. Increasing the energy level still more hardly enlarges the pixel any further. The thermal plates have an extremely steep gradation[34], which enables very stable processing with particularly sharp-edged screen dots.

Figure 76: Blooming during platemaking.



7.1.1 Printing Plate Imaging

Printing plate imaging now mainly takes place on CtP lines[31]. To demonstrate the advantages of CtP lines, the process of making a copy onto an offset plate on a CtF line will also be looked at. Blooming or side lighting influences the ink coverage when copying the films to the printing plates. In some films, the edge of the screen dot is not absolutely sharp – i. e. there is a gray zone.
Blooming can occur even on extremely hard-dot films with a sharp edge, since the photographic layer is always at a minimal distance from the plate and is itself approximately 1 μ thick. Dust particles between film and printing plate cause localized differences in tonal value known as a bad copy.
Reflections on the metal substrate and stray light also play a role. Normally, printers try to cover up the cutting edges on the film. This is done using the blooming effects described and possibly even a dispersion foil[35], and the dots that are generated are generally 'pointed'[36].
From these brief observations, it is immediately clear why the platemaking stage is now left out and the benefits of CtP lines are utilized.

The advantages of a CtP line can be summarized as follows:

- Ultra-sharp dot rather than unsharp analog copy.
- No specks of dust, cutting edges or bad copies.
- No more manual plate correction.
- Savings in terms of film and developing.
- High register accuracy.
- Greater range of tonal values.
- FM screens easy to use.
- Digital press presetting, resulting in faster setup, quicker inking up and less startup waste.
- End-to-end process automation in prepress, press and postpress, resulting in significantly higher capacity utilization of presses and postpress machinery.

7.2 Dot Gain in Print

The most important effect that needs to be taken into account when creating printing forms is the dot gain in print. This will be explained using offset printing as an example. The ink is applied to the plate cylinder via an inking unit, and the water, which is mixed with alcohol, is applied via a dampening system. From there, the ink is transferred to a blanket cylinder and only then to the printing stock. It's easy to see that the printed dots can be 'squashed flat' to a greater or lesser extent in this process. The resulting dot gain in print can be influenced by a number of factors, including the quantity of ink, the ink/water balance and the pressure of the cylinders. A large number of factors thus need to be kept absolutely constant to ensure stable printing.

Figure 77: Diagram of an offset press.

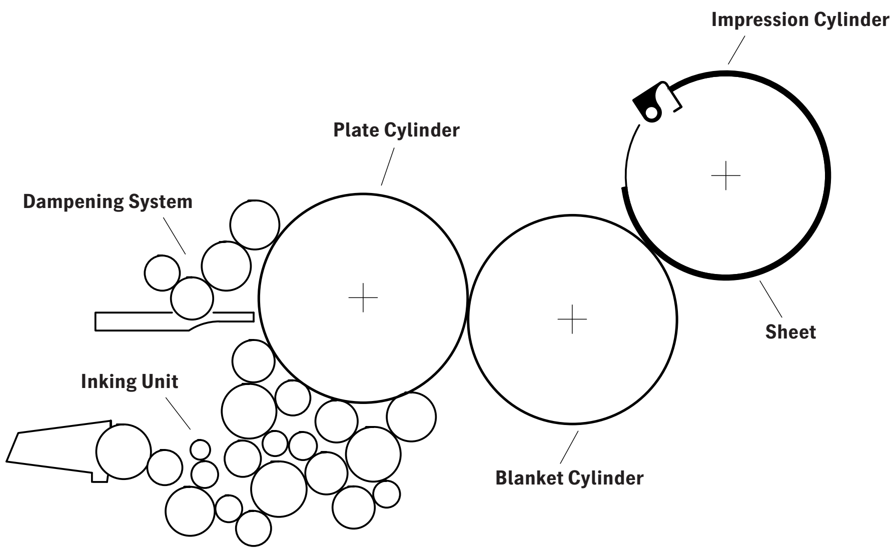
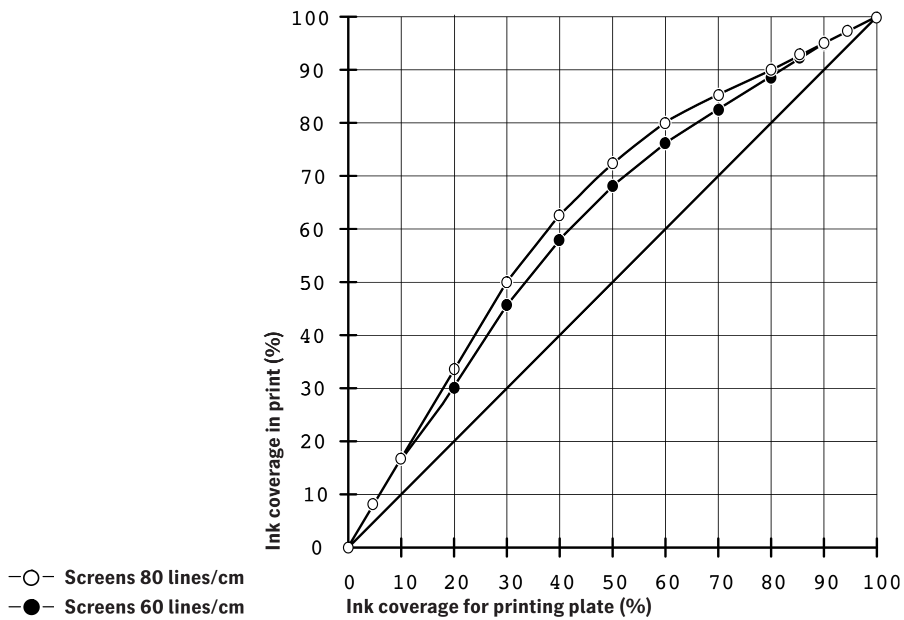


Figure 78: Example of a printing characteristic with significant dot gain in the midtone.



The main factor for dot gain in print is the light capture effect. The result of light capture effect in the reflective light densitometer is described in the section about density in the Tips and Tricks chapter.
The printing characteristic (curve) is obtained by plotting (or mapping) the ink coverage produced during printing against the dot percentage of the printing plate. This shows a significant dot gain in the midtone. The dot gain can vary quite considerably, depending on the press, printing conditions, type of paper and screen frequency. If one of these factors changes, a new process calibration is usually required.
Media-neutral generation of images suitable for both printing and electronic media is currently standard practice. (Only older images have a standard dot gain already integrated in the color gradation for the image scan.) The data is prepared for the output medium using ICC profiles.
It is then adapted to the current printing characteristic during electronic screening. This requires prior process calibration.

7.3 Process Calibration

Process calibration is a tool for controlling the dot gain of a printing process. It is closely linked to standardization.
The standardization of printing processes involves many other aspects besides dot gain, such as the properties of printing stock and inks, solid tinting (density), ICC profiles and the press itself. Although standardization does not give a printer complete freedom to express himself, good results are much faster to achieve, and this means there's also less startup waste. Standardization and automatic press setup combine to significantly boost productivity.
The purpose of process calibration is to match the dot gain of a printing process with a set process standard. Among other things, dot gain depends on the press, printing stock, inks, solid tinting (density) and, in particular, the screen and screen frequency selected.
The key pre-requisite for performing calibration is a stable printing process, in particular correct inking.
Process calibration is performed using a special calibration tool. A test page is imaged uncalibrated using the screen that is to be calibrated. A key element of the test page is the step wedges with tonal values of between 0 % and 100 %. A proof print of the page is then output onto the relevant printing material and measured densitometrically.
The user enters the data measured and the nominal values of a process standard in the dialog box of the calibration tool that then calculates the calibration characteristics for electronic screening. These characteristics are saved in a database and can be used subsequently in production. Information about the validity range of calibrations is stored so that the time-consuming calibration process does not have to be repeated from scratch for every screen combination.
The calibration characteristics obtained in this way are normally so good that the print results are in the tolerance range right away.
Even if you subsequently make color corrections, i. e. you are doing the job of a lithographer at the press, a good process calibration gives you sure, centered results, providing you with a solid base for any artistic designs needed.
Process calibration is mostly color-dependent. The main reasons for this are rheological[37] differences in the colors or different settings in the various inking units of a press.
With some screen systems, calibration is color-dependent even if all colors have the same properties. This is the case for the IS Y fine, RT Y45° K fine and Megadot screen systems due to the very different screen frequencies in the color separations.

7.4 Selecting Screen Frequencies

A screen should be fine enough that it cannot be perceived by the human eye. With a 150 lpi (60 l/cm) screen, the individual screen dots are just about discernable – this is the visibility limit. For monochrome images, reproduction with 150 lpi (60 l/cm) is sufficient. Conventional screens produce a somewhat larger rosette in the overprint, with the visibility of the rosette depending on the hue. Studies carried out by FOGRA have shown that the visibility of the rosette more or less corresponds to the visibility of a screen with a 1.5 fold period, i.e. the rosette would still be visible on an 200 lpi (80 l/cm) screen. High-quality artwork should therefore be printed using at least an 200 lpi (80 l/cm) screen.
However, printing aspects are often more important when selecting the screen frequency. The smallest possible dot or the smallest gap that can still be printed between the dots is a crucial factor here.
Because the human eye is very sensitive to densities in the shadows, it is important to print gaps that are as small as possible. In the shadows, losses of 1.0 % are already noticeable in the shadow definition.
The highlights are also of particular interest because there are numerous critical motifs in this tonal range.

The table below sets out the ink coverage with specific minimum dot sizes for various screen frequencies. Generally speaking, relatively coarse screens are used for printing because they're easier to process. The size of the dot that can still be printed depends on many factors, particularly the paper. Experience with FM screens has shown that dots with a diameter of 20 μ are still stable in print, but that difficulties are experienced with dots smaller than this.
This highlights a dilemma of conventional printing. With a finer screen, the screen dots are so small in the highlights that some of them fade away, producing a tonal range with unstable printing behavior. It's a similar story with the holes in the shadows. Highlight and shadow definition is therefore lost. The solution to this problem is Prinect Hybrid Screening or Prinect Stochastic Screening. These two systems allow stable printing of tiny dot sizes in the highlights and tiny holes in the shadows (see Chapter 4).

Screens of around 100 lpi (40 l/cm) have become the general standard in newspaper printing. A 150 lpi (60 l/cm) screen was used in Europe for printing magazines and catalogs, but now the 175 lpi (70 l/cm) screen, already the standard in South-East Asia, has become widespread. For artwork on coated paper[24], a screen of 200 lpi (80 l/cm) or finer is recommended.

Table 12: Smallest printable dot and maximum ink coverage.

Smallest printable dot

Screen frequency lpi	Screen frequency l/cm	Diam. μ	Stable printing %	Diam. μ	Stable printing %	Diam. μ	Stable printing %
100	40	10	0.1	20	0.5	30	1.1
150	60	10	0.3	20	0.6	30	2.5
200	80	10	0.5	20	2.0	30	4.5
300	120	10	1.1	20	4.5	30	10.2
400	160	10	2.0	20	8.0	30	18.1

7.5 Proofs

The aim of a proof is to predict the subsequent print result as accurately as possible. Because different demands are placed on a proof, various methods may be selected to produce it.

The fundamental requirement for a proof is to display the data content accurately on the image. Color fidelity is not of great concern here and proofs are often printed in black and white. This is what is called a 'content proof'. Even for this basic proof, however, a certain degree of accuracy is required. The objects on the page must be represented correctly and the text and graphics must be reproduced in the exact form to be used on the subsequent print. Fast laser printers or simple desktop inkjet printers are mostly used for this type of proof.

The next level up is for the proof to reproduce colors correctly. As far as possible, the proof should render the colors exactly as they will appear when subsequently printed. Often, the press is set based on the proof's color impression because the proof is the medium that the customer has seen and approved. This type of proof is called a 'color proof' and because it is often the basis for customer approval, it is also referred to as a 'contract proof'. This is what is normally meant when using the general term 'proof'.

Such proofs are now normally created using inkjet printers. These printers often use more than four colors so that they can also reproduce subtle shading. Another alternative is the 'sheet proof'. Large inkjet printers that output the entire print sheet complete with all control elements and colors that are as accurate as possible are used for this type of proof.

The challenge with color proofs is to be able to reproduce the color impression of the offset printing method with the printer's inks and the completely different printing method. Thanks to the color management methods now available (ICC profiles, calibration), the results are amazingly good and this has become the generally accepted method.

At the very highest level of proofing, however, the proof is not only required to reproduce the color correctly, but also the screen, matching the screen system used for printing as closely as possible. Such proofs are known as screen proofs and cannot be produced with the inkjet systems referred to above. Attempts have now also been made to reproduce the print's autotypical screen with inkjet printers, and moiré effects (e.g. between image content and print screen) can be detected prior to printing to a certain extent.

The most time-consuming screen proofs are proofs made on the printing press. This allows the screen used to be reproduced exactly. In addition, the same paper and the same colors can be used as in the production run.

If standardized, proofs made on the printing press should deliver reproducible true-color results. This also provides users with a lot of scope for varying color reproduction, making it possible to match various printing characteristics in the production run. However, it often remains to be seen whether the satisfactory result obtained from the proof will be produced at all on the production machine, and if it is, whether the result will be stable.

8 Tips and Tricks

This chapter deals with a number of tips and tricks that can be of assistance during your everyday work.

8.1 Angle Switchover

With conventional screens, it can sometimes be useful to switch the screen angles in order to get better results for certain motifs. In conventional screen systems, such as the IS Classic, the colors are assigned to the screen angles as shown in Table 13. Cyan, magenta and black, as the defining colors, are spaced 60° apart. The lightest color, yellow, has to be sandwiched in between them so that it is only 15° away from its neighbors.

Table 13: Input and output angles for the IS Classic screen system.

Angle Switchover		
Color	Input angle	Output angle
Cyan	15°	165°
Magenta	75°	45°
Yellow	0°	0°
Black	45°	105°

When conventional screen systems are used, the smaller distance between yellow and its neighboring colors can lead to a slight yellow moiré in the print. Usually it is not visible. This can be minimized if necessary by switching the screen angles, depending on the motif. This applies regardless of the method used to generate conventional screens or their approximations.
If skin tones are predominant, then the angle allocation specified above is the best solution. Greens (e. g. vegetation) are generally inherently structured, so a slight moiré will not be visible.
If smooth gray-greens are predominant, then switching the screen angles of cyan and magenta is recommended to avoid any moiré between cyan and yellow. Only the screen angles for magenta should be switched with cyan or black. We strongly recommend that yellow is not assigned to another angle.
The relevant user manuals will describe how to switch the angles.
The illustration opposite shows two rectangles with a critical hue that were imaged in the IS Classic screen system using a 133 lpi (54 l/cm) screen and 2540 dpi (1000 l/cm) imagesetter resolution.

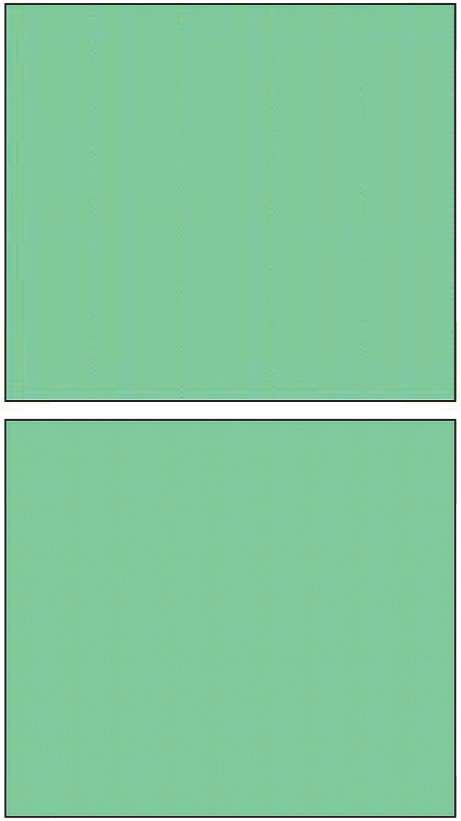


Figure 79: By switching the angle, better results can be achieved for certain motifs or critical hues (top: standard setting, bottom: cyan and magenta switched).

In the top rectangle, the angles are not switched. In the bottom one, they are. The effects are particularly clear in smooth areas.
Using a finer screen reduces the visibility of a slight yellow moiré. This removes the need to switch angles in most cases.
Alternatively, the IS Y fine or RT Y45° K fine screen systems can be used, since they have no yellow moiré.

8.2 Vignettes

Vignettes are ideal for demonstrating the sensitivity of the human eye. In the shadows especially, the human eye is able to distinguish even very slight differences in dot percentage.
The following optical illusion is interesting. With a vignette composed of visible tonal value levels, edges are perceived sharper such that each level appears darker towards the lighter side than on the darker side of the vignette. This property of the eye means that particularly high demands are placed on vignettes if they are to appear smooth.

8.2.1 Generating Vignettes

PostScript Level 1 only allowed vignettes to be generated using neighboring graphic objects (e. g. rectangles) with a gradually changing color value. Alternatively, it was possible to use a synthetic image representing a vignette. Both methods only allowed graduation with 8-bit accuracy (= 256 tonal value levels), which just about produced acceptable results. In most cases, however, some slight stepping was visible. This problem was partly solved by using an image editing program to generate a vignette with a sufficiently high resolution as an image and superimposing a slight noise. This improved the quality but the smoothness achieved was not particularly good by today's standards.
With PostScript Level 2, Adobe introduced the option of 12-bit images, which theoretically allowed 4096 tonal value levels per color channel. Partly due to computing speed considerations, however, only 8 bits are used internally in RIPs.
With PostScript 3, Adobe finally introduced smooth shades for vignettes. The vignettes are described using mathematical functions. The type of vignette can be selected, e. g. a linear or radial vignette, and other more complex two-dimensional vignettes where the color value required is only indicated by the job at certain locations in the area. It is also possible to select the type of mathematical function, i.e. a linear or exponential series of values from a start to an end color value, or the function can be indicated using reference points. The special feature of smooth shades is that the RIP rather than the job is responsible for generating sufficiently finely graduated tonal values. The intermediate values are interpolated between the color values indicated by the job. The RIP also takes into account the number of tonal value levels allowed by the screen's threshold matrix. If the screen is based on 8 bits, smooth shades too are only processed using 8-bit graduation. If the screen is based on more than 8 bits, however, vignettes are also generated with a correspondingly higher number of tonal value levels. This produces smooth vignettes.
Explaining how various applications generate vignettes would require a section all of its own. Most professional graphics and layout programs now generate vignettes with smooth shades. Some applications, in particular older versions, do not yet use these features and generate vignettes using the old methods, i. e. they juxtapose strips of gradually increasing tonal values. If you're lucky, the full 256 tonal value levels are used and the vignette's transition from 0 % to 100 % dot percentage is completed in 256 graduations. This produces useable results, in particular if the vignettes do not extend right into the shadows or they are relatively short.
Some applications still try to save memory and computing time by generating vignettes from as few levels as possible – a lasting legacy from the days before powerful computers. To do this, the application requests the imagesetter resolution set on the RIP and the screen frequency and uses this information to calculate the number of assumed tonal value levels.
For example, with an imagesetter resolution of 1000 l/cm and an 80 l/cm screen, a screen cell is made up of approximately 12 x 12 imagesetter pixels. The application then wrongly assumes that only around 144 tonal value levels can be displayed and, consequently, the vignette is only made up of 144 levels. This is, of course, far too few, and stepping can clearly be seen.
As a remedy for vignettes generated using the 'old-fashioned' methods, with PostScript 3 Adobe introduced not only smooth shades but also the 'idiom recognition' facility. The PostScript files generated from applications include a header which in turn contains a small PostScript subroutine for generating a vignette. Further into the PostScript job, the subroutine is simply called up with the required parameters, e. g. the start and end color value. The subroutine of older applications then calculates the limited number of tonal value levels (which nowadays is unacceptable) and creates the vignette from individual areas.
Idiom recognition enables the subroutine to be replaced. Both the unwanted subroutine and its replacement must be saved in the RIP for this purpose. If idiom recognition is enabled, the PostScript Interpreter identifies the subroutine when processing the job and replaces it. This makes it possible to create a smooth

shade from an 'old-fashioned' vignette. Unfortunately, the applications' vignette subroutines often differ from version to version and the application manufacturers rarely provide the necessary PostScript idioms. Creating idioms is a time-consuming business and, consequently, RIPs only include replacements for some of the common applications and their various versions.
Idiom recognition is a technology based solely on PostScript. If an application generates PDFs directly, idiom recognition in the RIP has no effect.
If a PDF is generated from PostScript by Acrobat Distiller, idiom recognition is an option. In such cases, vignettes are converted into smooth shades.
Otherwise, Acrobat Distiller takes into account that it is not possible to create the appropriate sets of idioms for all versions of every single application.
Several neighboring rectangles with a similar tonal value that have been created by the PostScript job using a program loop are converted into smooth shades. In some cases, the result can be undesirable and the option must be disabled.
A much underestimated cause of banding in vignettes can be extreme process calibration. If too many measured values are used for process calibration or the curve is not smoothed out, kinks or steep sections can occur. The resultant banding is particularly visible in short vignettes. The reason for this is that tonal value levels are unevenly distributed or lost during screening
With Heidelberg screening, this is largely avoided. As already described in the chapter on screening methods, a multidot technology is used. This means that there is always a sufficient number of levels (more than 1000) to display a vignette smoothly. Even if a PostScript job only uses 256 levels, these are reproduced evenly.

8.3 Media and Scanner Moirés

Moirés are disturbances, as described in Chapter 1.3. They can occur when unsuitable screens are overprinted, and also between the print screen and fine, uniform patterns in the original.
Examples of this include fabrics such as those shown in the Prinect Stochastic Screening print example. These types of moiré can be avoided by using the FM screens described earlier.
Similarly, moirés can also occur between the original and a digital camera's pixel screen or a scanner's scanning screen. These moirés cannot be eliminated using a downstream process. They can usually be avoided by re-recording the original at a higher resolution.
Very pronounced moirés sometimes also occur when scanning originals that have already been screened. Reliable descreening can only be achieved in these cases by using special filtering processes.

8.4 Spot Colors

Spot colors are often just printed as solid tints. In such cases, there are no problems with screens and moirés.
For screened spot colors that are overprinted with other screened colors, however, the situation is different. Here, careful consideration needs to be given to how best to avoid moirés because conventional screen systems are only designed for four colors. The normal approach is to allocate the spot color to the angle of a process color with which there is as little overprinting as possible.
Alternatively, the fine screen from RT Y45 K fine can be used for the fifth color. It is also conceivable to combine FM screens or AM and FM screens.
For the special case of duotones[38] and tritones[39], optimum combinations can be found with all screen systems.

8.5 HiFi Color (Seven-Color Printing)

HiFi Color is seven-color printing with black, cyan, blue, magenta, red, yellow and green. It will be dealt with here from the aspect of screening. This book does not cover the creation of appropriate profiles for the color separations.
In the separation process, each hue is generated using just three colors. Black provides the gray component and any hue can be generated with two neighboring colors. For example, all hues between red and yellow can be created using these two process colors and black. The same applies for all other hues. This means that it is possible in 7-color printing to use just 3 different screen angles. A maximum of 10% of a complementary color can be added to darken the color. Despite the double use of screen angles, there is no risk of color shifts.
Table 14 suggests allocations of screen angles to colors for the IS Classic screen system. Prinect Hybrid Screening, rational screen systems or Megadot can, of course, also be used with the relevant screen angles.

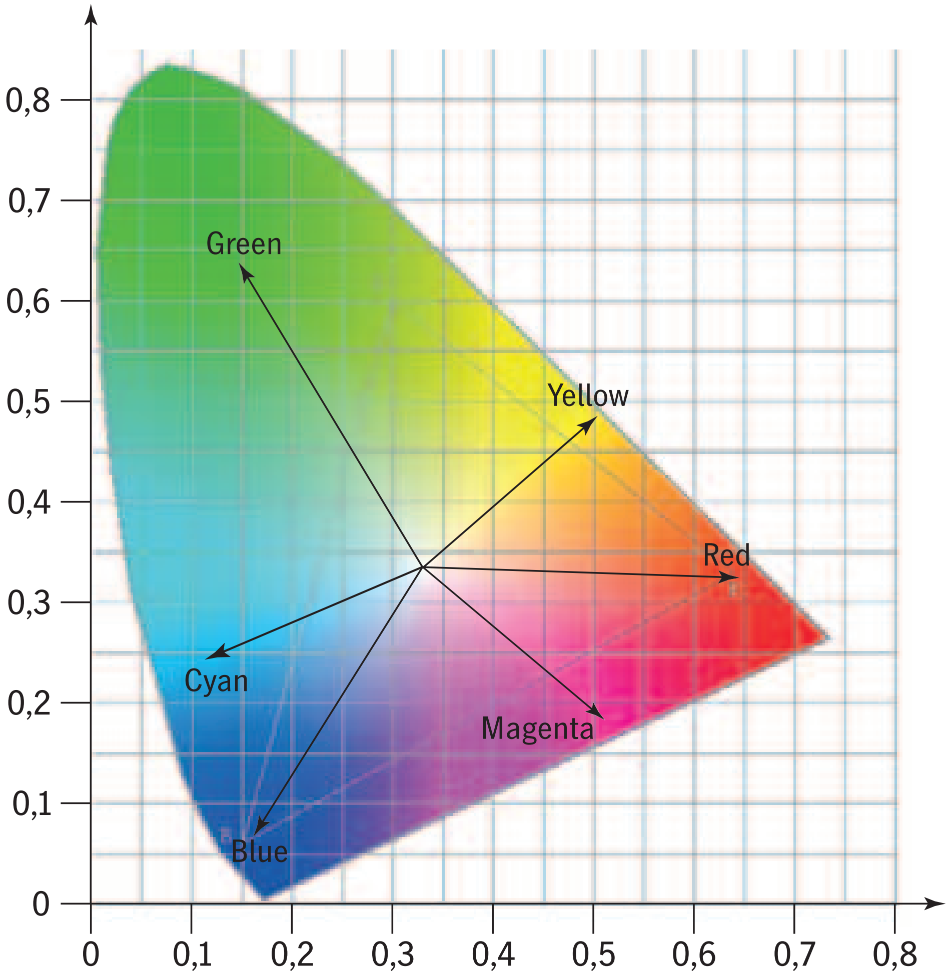


Figure 80: Position of process colors in 7-color printing. Six chromatic colors are arranged around the central black.

Prinect Stochastic Screening is ideal for the high quality demands of HiFi Color. The allocation of the 'screen angles' to the colors is also as indicated in Table 14.

Table 14: Color allocation in 7-color printing.

HiFi Color	
Color	Output angle
Cyan	165°
Blue	105°
Magenta	165°
Red	105°
Yellow	165°
Green	105°
Black	45°

8.6 Hexachrome Printing

Hexachrome printing is a 6-color printing method using black, cyan, magenta, orange, yellow and green. It will be dealt with here from the aspect of screening. This book does not cover the creation of appropriate profiles for the color separations.

In contrast to 7-color printing, hexachrome printing requires more than three screen angles. Because there is an odd number of chromatic colors, they cannot be assigned alternately to just two different screen angles. The following screen combination is therefore suggested:

Black as the dominant color is assigned to 45° fine black in the RT Y45° K fine screen system. The five chromatic colors cyan, magenta, orange, yellow and green are then assigned to 165°, 105°, 165°, 45° (0°) and 105° in the IS Classic screen system. If applied accordingly, the IS Y60° and IS Y30° screen systems can also be used for the chromatic colors.

This means that with hexachrome it is possible to generate each hue using just three colors. A maximum of 10 % of a complementary color can be added to darken the color without causing any risk of color shift.

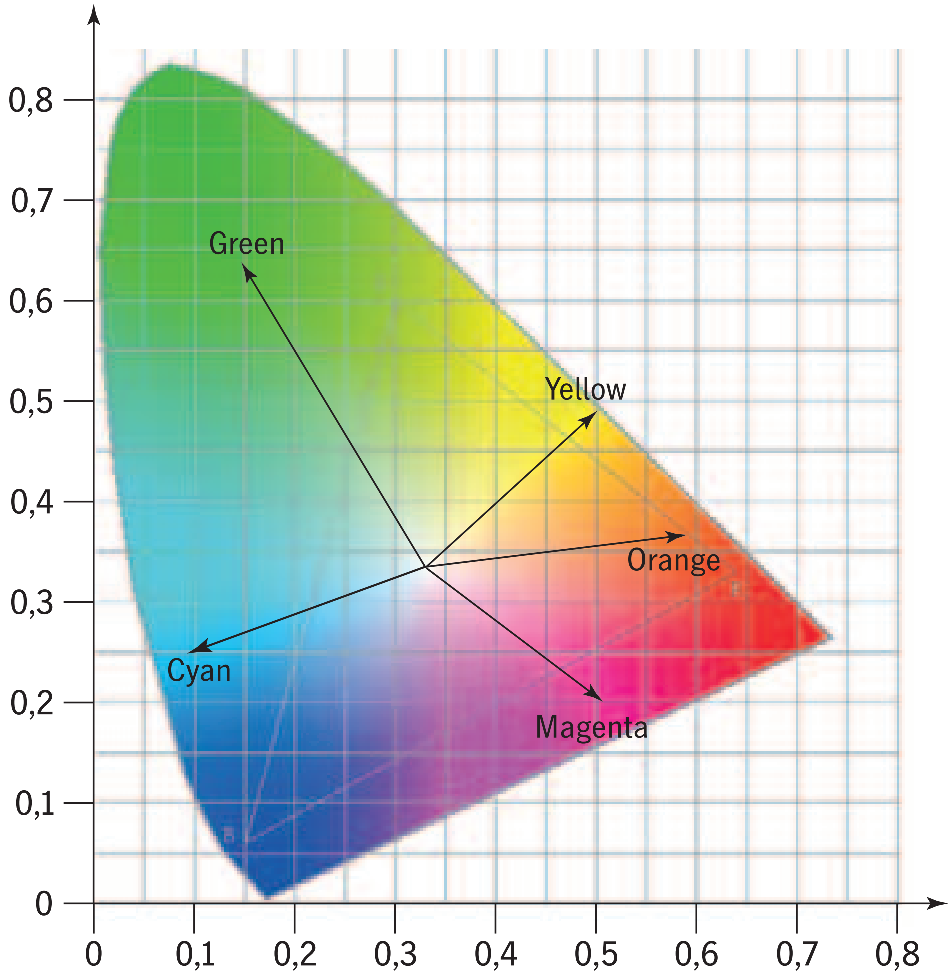


Figure 81: Position of process colors in hexachrome printing. Just 5 chromatic colors are arranged around the central black.

Prinect Stochastic Screening is ideal for the high quality demands of hexachrome printing. The allocation of the ‘screen angles’ to colors is as shown in Table 15, with yellow at 0° and black at the ‘output angle’ of 45°.

Another item to note: Cyan, magenta and yellow generally have colormetrics that are significantly different from those familiar from 4-color printing.

Table 15: Color allocation in hexachrome printing

Hexachrome printing

Color	Screen system	Output angle
Cyan	IS Classic	165°
Magenta	IS Classic	105°
Orange	IS Classic	165°
Yellow	IS Classic	45°/(0°)
Green	IS Classic	105°
Black fine	RTY45 K fine	45°

8.7. Density Measurement

The reflectivity[41] of a printing plate or print can be measured as a dot percentage going from 0 % to 100 %, or as a density. Normally, the final density of a print is measured in logarithmic units as a density. This is recommended since light absorption is proportional to the log of the thickness of the light-absorbing ink layer. Density is, therefore, a measure of the thickness of the ink layer.

Density (D) is defined as the negative logarithm to the base of 10 of transmission[40] or reflectivity[41] (R):

$D = -\log_{10}(R)$.

Table 16: Reflectivity and print density

Density		
Reflectivity (R)	Dot percentage	Print density
1.000000	0.0000 %	0
0.100000	90.0000 %	1
0.010000	99.0000 %	2
0.001000	99.9000 %	3
0.000100	99.9900 %	4
0.000010	99.9990 %	5
0.000001	99.9999 %	6

Screened surfaces are mostly measured as dot percentages (F). In densitometers, these values are simply converted using the following formula:

$F = 10^{-D} \times 100$

To give an overview, Table 16 lists the values for reflectivity, dot percentage and print density.

8.7.1 Measuring the Dot Percentage in Print

If the reflective capacity of a print is measured, then measuring errors will mainly arise from light gathering effects. Figure 82 shows just how these systematic measuring errors occur. Other sources of accidental measuring errors include stray light caused by dust. The figure opposite shows how light reacts in the measuring head of a reflective light densitometer. The original is illuminated from the side by condenser lenses, and a centrally positioned lens transmits the diffusely reflected light onto a photocell that measures it. Light mirrored on the surfaces does not enter the lens in this configuration. In Figure 81, the lenses displayed are far too small compared to the screen dots and too close to the paper surface.

The light capture effects mainly occur by the light not being reflected directly at the surface, but rather by it penetrating the paper and only being scattered

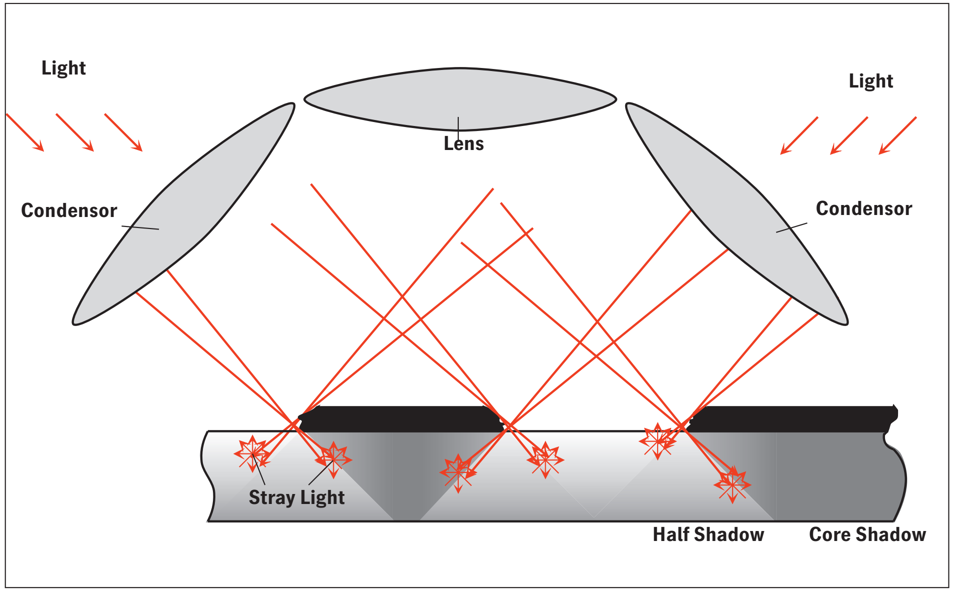


Figure 82: Light capture effects in a reflective light densitometer.

back from this point. Part of the light is scattered below the screen dots and absorbed by the inked areas; in other words, it is ‘captured’ under the screen dots. A half-shadow forms around the printed dots and increases the size of the dot by a few μ. That doesn’t sound like much, but on a 150 lpi (60 l/cm) screen, this represents a dot gain of approximately 12 % in the midtone range.

The dot gain measured in print is mainly due to light capture effects. Such effects do not need to be taken into account in printing characteristics since they are already implicitly factored in there.

Another item to note for practical application purposes: Prints should only be measured on a black or dark gray background. This minimizes measuring errors caused by any printing on the reverse side showing through or by differing backgrounds and results become significantly more reproducible.

8.7.2 Measuring the Dot Percentage on Printing Plates

As is apparent from the following details, it is essential to use a specially designed densitometer to measure printing plates.

In addition to the difficulties of measuring dot percentages already dealt with, printing plates pose the further problem that the contrast between printing and non-printing parts is often very small. This fact alone makes the measurement unreliable.

When calculating the dot percentage (F), it is also necessary to take into account the white density (DW) and full-tone density (DS):

$F = (10^{-D} - 10^{-DW})/(10^{-DS} - 10^{-DW})$

Some densitometers incorporate the relevant corrections but users should check the manufacturers' documentation to see if this is the case.

The best way to measure printing plates is using a digital camera that scans the plate's surface and an evaluation system that establishes which pixels are exposed and which unexposed and calculates the dot percentage from the relevant ratio. Obviously, this method produces the most reliable results.

However, even this method has its limits. The threshold differentiating between exposed and unexposed pixels in the measurement is highly critical; a tiny shift results in significant deviations in the measured value. For example:

With a 150 lpi (60 l/cm) screen, an error of just one μ in the dot edge determined causes an error of approximately 1.75 % in the calculation of the dot percentage.

To sum up, measuring the dot percentage of printing plates was already commonplace at the time of going to press. Nevertheless, absolute measured values should be treated with some caution. Relative values that check the constancy of an imaging path are reliable though, in particular if the same device is always used and the measurements are performed under constant conditions.

Footnotes

1 PostScript is the worldwide standard device-independent page description language developed by Adobe® to output text, graphics and images. It can also be used as a programming language.
2 PDF (Portable Document Format) is a page description format developed by Adobe which incorporates the experience gained with PostScript. Its purpose is to ensure the system/hardware-independent exchange of documents containing text, graphics and images.
3 JDF (Job Definition Format) is a data format developed by Adobe to control output devices.
4 A RIP is a Raster Image Processor. It translates the text, image and graphic elements defined in a page description language into a form that the output device (printer, proofer, filmsetter or platesetter) can represent. In most cases, image, vector or other graphic information is used to generate a bitmap.
5 (l/cm) Applying the rules on SI units to the letter, it should really be cm^{-1} rather than l/cm, but the old notation has been used to aid comprehension.
6 Black is assigned K for Key, because the B is already used by Blue.
7 FOGRA Symposium 1989.
8 When a signature runs through a printing press, slight deviations in angle or position inevitably occur from one printing unit to the next. These deviations, known as misregistration or register errors, must not be more than 1/100 mm. If misregistration is larger, the print will lose its sharpness, and color blanks will become visible around the contours of colored areas when viewed under the magnifying glass. Misregistration also very frequently causes color shift.
9 In the printing industry, the dark areas in a print or film are known as the shadows. Light areas are known as highlight or light-tone and the mid-range as the midtone.
10 In case you need a math refresher: If you draw a perpendicular line from one side of an angle to another, you get a rectangular triangle. Its tangent is a ratio of side to base. Arctangent = the opposite of a tangent, it gives the angle of the tangent value.
11 Dither = shiver, erratic movement.
12 The term ‘fast-scan direction’ means the rapid movement of a laser beam over film or printing plate. It generally refers to the direction of rotation of the laser mirror or drum, in contrast to slow-scan direction which generally refers to the feed direction.
13 Artifacts are artificial elements that are not present in the original. In the Error Diffusion method described in this book, contours are sharpened in a certain direction. Additional lines can form along these contours. Saying that an image has artifacts is an indirect way of saying that it has imperfections.
14 The mathematical term matrix is loosely used to describe a two-dimensional table that assigns coordinate vector reference values for the density.
15 Redundancies are repeated or additional elements that can be used to detect or correct transmission errors.
16 Address increments are added to the current address to obtain the next one.
17 On-the-fly describes calculations that are processed while the machine is in operation. With normal pages, the RIP process, including screening, operates faster than the imagesetter, so the imagesetter can image at full speed. However, a RIP interpreter can slow down an imagesetter when it is processing very computation-intensive pages.
18 Banding, or shadestepping, occurs when there are too few steps in a blend or vignette. See Chapter 8.2, Tips and Tricks, to learn more about vignettes.
19 The area where individual screen dots just about to join at the corners is known as dot chain (see section 8.2, Vignettes).
20 Slurs and doubling are printing press errors that become apparent through the widening or doubling of fine lines in the circumferential direction. In offset printing, the printed image on the plate cylinder is printed first on a blanket cylinder and then on paper (see Chapter 7.2 Dot Gain in Print). These errors occur when the plate cylinder and the blanket cylinder are not synchronized exactly.
21 Offset/gravure conversion was introduced in the mid-1980s, making it much easier and cheaper to produce rotogravure cylinders. Previously, photographic contone (continuous tone) originals were scanned and engraved in gravure cylinders to produce color separation. This contone process was complex and relatively unstable. Moreover, a great deal of postprocessing work needed to be carried out on the impression cylinders. An optical trick while scanning enabled offset lithos to be descreened. This meant that moirés were avoided between the offset screen of the lithos and the engraving screen of the gravure cylinders. This litho process was much simpler and more stable than the contone process. Furthermore, it also minimized complex postprocessing work on the gravure cylinders.
22 The Greek mathematician Euclid based his Euclidean theory of geometry on a set of axioms. Axioms are basic principles from which all others are derived.
23 In film, gradation describes the correlation between the amount of light and the resulting density. With scanners, gradation describes the correlation between the lightness of the original and its digital output value.
24 Art paper is coated paper. It is coated with a layer of fine fillers (natural gypsum, titanium white, chalk, talcum or porcelain clay) and then reglazed. This improves the white content and the gaps between the fibers are filled in. The surface of uncoated paper does not contain any fillers enhancing the smoothness or gloss.
25 In a composite workflow, the PostScript description of each page contains information about all the color separations. This is in contrast to a separated workflow, in which each page is only one color separation.
26 A plug-in is an additional product module that performs certain functions the original program could not do or that makes certain functions available.
27 The user input is converted in the screen filter to values that guarantee good overprints (see context).
28 DCS = Desktop Color Separation is an EPS file format that contains the four color separations and a file for the placement of images.
29 Delta Technology is a RIP and workflow product from Heidelberg.
30 Overinking and underinking are incorrect press settings. For stable and reproducible print results, it is necessary to set the print density, i.e. the amount of ink applied, as specified in the printing standard. With overinking, too much ink is applied, making the print too dark and causing the shadows to fill in. With underinking, too little ink is applied, making the print too light, and possibly causing the highlights to fade away.
31 In Computer-to-Plate (CtP), the data which has been prepared for printing is imaged directly on the printing plate – i.e. without being first transferred to film.
32 The gray scale or step wedge is a measuring strip with areas of gradually increasing density. It is used to check film linearizations or printing characteristics.

33 A photopolymer is a light-sensitive synthetic material.
34 A 'hard-dot' film has a steep gradation curve. This means that a film does not react to small quantities of light, but only after a relatively high threshold is reached. Above this threshold, only a small amount of additional light is required to expose the film to saturation.
35 A dispersion foil scatters light, thereby making it more diffuse. This significantly increases blooming so that cutting edges cannot be copied.
36 Screen dots are copied pointed if they are made smaller through overexposure and blooming.
37 Rheology concerns the flow phenomena of liquids, colloidal systems and solids under the influence of external forces.
38 Duotones are graphic objects composed of two colors only, mostly spot colors. One of these colors is often black.
39 Tritones are graphic objects composed of three colors only, mostly spot colors. One of these colors is often black.
40 Transmission is the ratio of transmitted light to irradiated light.
41 Reflectivity is the ratio of reflected light to irradiated light.

Notes

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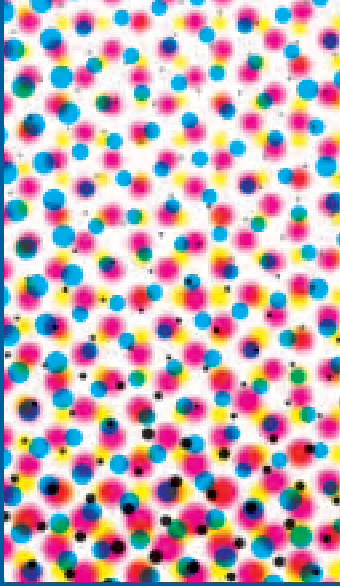

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