Technical Information: Resolution and Screen Ruling

The creation of a halftone has long been a craft that took experience and skill to perform well. With the introduction of easily available methods for digital halftoning, many more people need to develop skills for scanning and reproducing photographs. To make your halftones look as good as possible, it is important to know some of the rules that govern digital halftones. Following these rules will not only improve the look of your halftones, but will also result in lower output times. This article is about black and white halftones, but the same rules apply to color separated halftones.

The terminology

Defined below are some basic concepts that are used in this article:

Halftoning is the process used to convert a continuous tone photograph into a pattern of tiny dots which may be easily printed on a lithographic press.

Dot percent is a way of describing the gray value of an area of halftone dots. Dot percentage runs on a scale from 0% to 100% where white equals 0% and black equals 100%. Shades of gray get darker as the dot percentage gets higher. In a coarse tint (see Figure 1) it is easy to see how the size of an individual halftone dot affects the shade of gray produced.

Figure 1 - Dot percent scale from 0% to 100% in 10% steps at a coarse screen ruling.

Screen ruling is a measure of the fineness of a halftone screen – the higher the number, the finer the screen. A 150 line per inch halftone means that in each inch there are 150 lines of halftone dots.

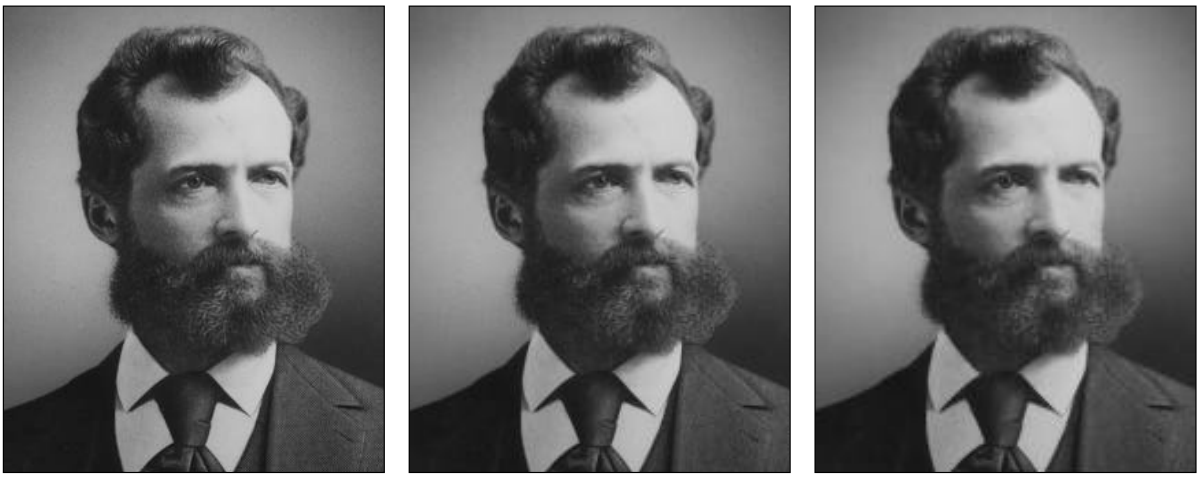


Figure 2 - Ottmar Mergenthaler at 60, 90, and 120 lines per inch.

Figure 3 - 0° (left) and 45° (right) screen angles. The screen ruling is 20 lpi.

Screen angle is the orientation of a halftone pattern as measured from a horizontal axis. A 45° angle is commonly used for black & white halftones. (See Figure 3.)

The number of grays that a digital halftone can produce is a function of the screen ruling of the halftone screen and the resolution of the imagesetter. The human eye can distinguish anywhere between 50 and 200 levels of gray. When too few levels of gray are used, a phenomenon called posterization occurs. (See Figure 4.)

Resolution is the ability with which an imagesetter can render detail. This is a combination of a number of factors, most importantly, addressability and laser spot size. The terms addressability and resolution have often been used interchangeably, but actually addressability has a slightly different meaning. Addressability is a measure of how many marks an imagesetter can make within a linear inch. Because the industry convention is to use the term resolution instead of addressability, the term resolution will be used throughout this document.

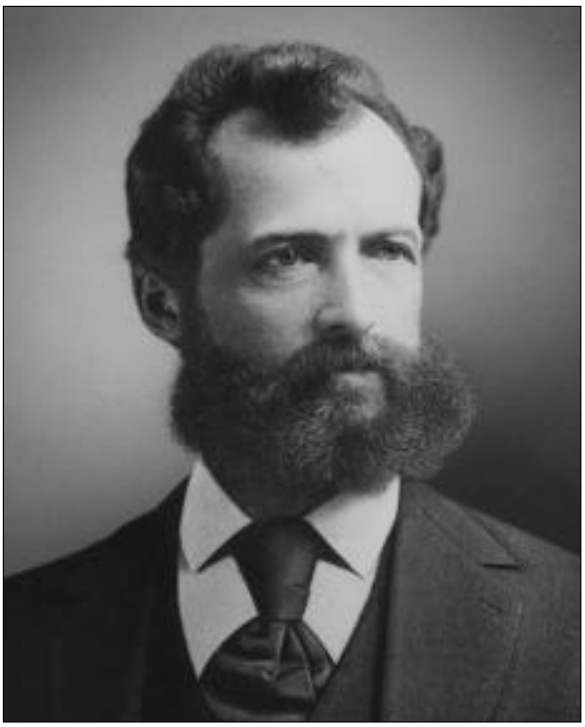
If you understand these concepts, you will understand digital halftones, and then you can avoid potential problems in creating digital halftones. For example, poor calibration is a function of dot percent; moiré in color separated work is a function of screen angle and ruling; and posterization is a function of the screen ruling, resolution, and the number of grays.

Resolution and screen ruling

The relationship between the screen ruling of an image and the resolution at which it is output plays an integral role in image quality. Many of you have seen this formula:

$$\textbf{(Resolution/Screen ruling)}^2 \textbf{ + 1 = Number of Grays}$$

This formula indicates that if screen ruling remains constant, a higher resolution results in more grays. Figure 4 illustrates this formula. The two images in Figure 4 are from the same scan. The screen ruling remains the same. The resolution changes and therefore the number of grays changes. Here are the calculations (when calculating grays, round to the nearest whole number):



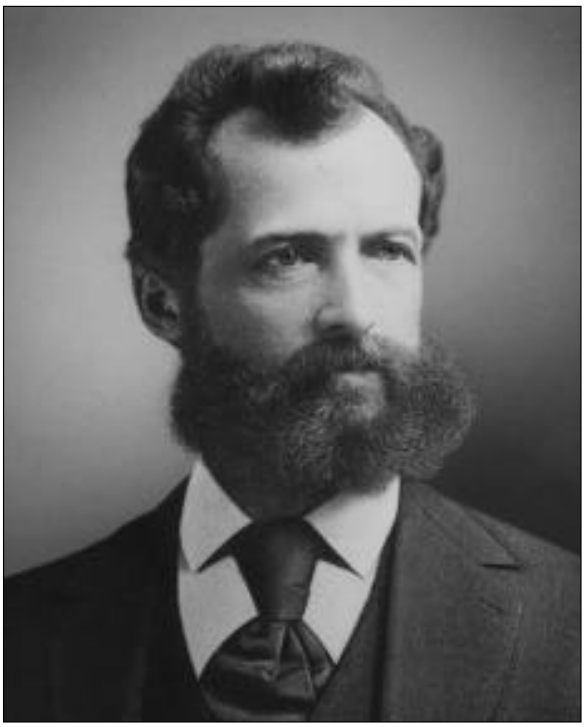


Figure 4 - The image on the left was output at 635 resolution, the image on the right was output at 2540 resolution. Both images have a screen ruling of 150 lpi and a screen angle of 45 degrees. This shows the difference between 19 levels of gray (left) and 256 levels of gray (right).

Highest screen ruling that yields either 256 or 100 levels of gray at the following resolutions:

Res.	256 grays	100 grays
300[1]	19 lpi	30 lpi
423[1]	26 lpi	42 lpi
600[1]	38 lpi	60 lpi
635[1]	40 lpi	64 lpi
846	53 lpi	85 lpi
1016	64 lpi	102 lpi
1219	76 lpi	122 lpi
1270	79 lpi	127 lpi
1693	106 lpi	169 lpi
2032	127 lpi	203 lpi
2438	152 lpi	244 lpi
2540	159 lpi	254 lpi
3251[2]	203 lpi	325 lpi
3386[2]	212 lpi	339 lpi

[1]Selecting higher screen rulings at these resolutions will result in posterization.
[2]The 3251 and 3386 resolution settings provide 256 levels of gray for screen rulings up to 203 lines per inch.
Note: The resolution steps 1219, 2438 and 3251 appear only on the Linotronic* 630 imagesetter.

Image output at 635 resolution, 150 lines per inch, 45 degree angle

$(635/150)^2 + 1 = 19$ Grays

Image output at 2540 resolution, 150 lines per inch, 45 degree angle

$(2540/150)^2 + 1 = 288$ Grays

Nineteen grays are not enough to create a smooth looking image, and therefore the image is posterized. There isn't necessarily an advantage in increasing the resolution; although the number of grays will increase, so will output times. Since this is a quality and production issue, you must make your own choice. However, we can give you some guidelines.

Blends (also called graduated tints, gradations, fountains, degradés or vignettes) require as many levels of gray as possible (up to the 256 limit set in PostScript**.) Any value between 100 and 256 levels of gray is usually acceptable for digital halftones. Dividing 10 into the resolution gives you the screen ruling that permits 100 levels of gray. Dividing 16 into the resolution gives you the screen ruling that permits 256 levels of gray. The chart to the right shows the range of screen rulings that are appropriate for a given resolution (when levels of gray are the main concern.)

Follow the 256 levels of gray column down to the screen ruling that is closest to your requirement. Note the resolution. Do the same for 100 levels of gray. For example, this chart indicates that for a 100 line per inch halftone, the resolutions 1016 and 1693 produce around 100 and 256 levels of gray respectively. Since the resolution steps 1219 and 1270 fall in between 1016 and 1693, they should also be considered. To have 256 gray levels available in your halftone screen, choose 1693. The final choice of resolution depends on the steps available on your output device and also your quality requirements.

Choice of screen ruling

The type of paper used is a major factor in determining what screen ruling to choose. Your printer should recommend a screen ruling depending upon the paper and printing press that will be used for the job. As a general guideline, halftones printed on newspaper stock require screen rulings of 60 to 85 lines per inch. Higher quality uncoated paper may require 100 lines per inch halftones, while coated papers (depending on quality) may handle screen rulings of 120 to 200 lines per inch. If too high a screen ruling is used, there is a chance that highlight halftone dots will not print properly (which results in a loss of highlight detail). Also, in shadow areas halftone dots will tend to fill in (which darkens the image and causes loss of shadow detail).

Exceptions to the rule

The lack of gray levels at low resolutions is particularly apparent with 300 dot per inch laser printers. There simply isn't enough resolution to produce even a 60 line per inch screen ruling with a reasonable number of grays. There have been some techniques developed for laser printers which seemingly break the resolution/screen ruling/gray level rule. What these techniques do is to group four halftone dots together into a little subset. It is as if you divided each halftone dot into four parts. In this way you can get a pretty good looking 60 line per inch screen off of a laser printer, but in reality, this is really a souped up 30 line per inch screen. The problem with these techniques is that although the halftone appears to be 60 lines per inch, it is only able to show image detail at the level of a 30 line per inch halftone. However, this is a very reasonable tradeoff for a low resolution laser printer. Some recent efforts have been made to use this kind of technique at higher resolutions on imagesetters. The real test of these techniques will be their success at holding image detail.

Conclusion

You have seen how the choice of screen ruling and imagesetter resolution play an important role in the quality of a halftone. However, that only represents the output (or imagesetter) side. The input side (the scanner) plays an important role as well. The scanner resolution determines the file size and has a strong effect on output time and ultimate quality. That subject is the topic of another Linotype-Hell technical information piece: *Scanned File Size*.

Comments

Please direct any questions or comments to:

Jim Hamilton, Marketing Department
Linotype-Hell Company
425 Oser Avenue
Hauppauge, NY 11788 (516) 434-2717

Ottmar Mergenthaler, inventor of the first Linotype* machine, is the subject of the photographs shown in this article. The Linotype machine, a type composition machine that cast the metal pieces and composed them into a line of type, has been called one of the ten greatest inventions in the history of the world. More than 100,000 of them were sold between 1886 and 1971. This photo shows Mergenthaler at age forty, five years before his death in 1899.

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